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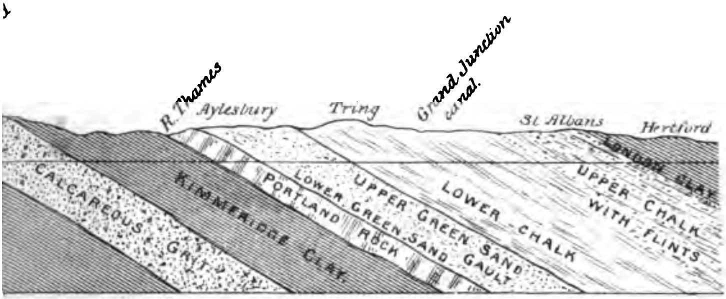

Collins' Elementary Science Series.

AGRICULTURAL TEXT-BOOK,

EMBRACING

SOILS, MANURES, ROTATIONS OF CROPS, AND LIVE STOCK,

ADAPTED TO THE REQUIREMENTS OF THE SYLLABUS OF THE SCIENCE AND ART DEPARTMENT, SOUTH KENSINGTON.

BY

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PREFACE

An endeavour has been made in the following pages to supply systematic information upon some of the principles lying at the foundation of successful land cultivation. No attempt has been made to describe the details of crop cultivation, because such an attempt would have carried me beyond the prescribed limits of this little work, and because it is advisable that an ELEMENTARY text-book should deal with principles rather than with practical details. An intelligent idea of the origin and properties of soils is a good foundation for a superstruction of knowledge regarding their tillage and improvement. In the same manner, a knowledge of the composition and requirements of plants throws a flood of light upon the uses of good cultivation and of fertilisers.

Habit of growth, and other peculiarities of cultivated plants, must be studied if we are to understand the theory of rotations. The time a crop occupies the field, the season at which it is sown, the length of its roots, and the direction in which they ramify—all are important considerations affecting the rotation or proper succession of crops.

The close connection between live stock and crop cultivation has rendered it necessary to devote a short section to our most important domestic animals. The Appendix tables, for which I am indebted to the works of

Dr Emil Wolff, of Hohenheim, will, I trust, be found useful in enabling the student to form an estimate as to the comparative feeding value and manurial value after consumption of a large number of feeding materials.

Several familiar chemical terms have been abandoned, in accordance with the usage of the best teachers. Hence, carbonic acid, phosphoric acid, and sulphuric acid, are spoken of as carbon dioxide, phosphorus pentoxide, and sulphur teroxide. Similarly, sulphate of lime is now described as calcium sulphate, carbonate of lime as calcium carbonate, and phosphate of lime as calcium phosphate. The nomenclature in the case of other salts is modified upon the same principle.

So much has been written upon the relative importance of PRACTICE and THEORY, as applied to Agriculture, that a few words upon these two aspects from which the art may be regarded may not be considered out of place. Good practice must and always will be in accordance with sound theory. It is impossible that any system or proposal should be "all very well in theory," and yet not be practical. This is a loose mode of speaking, for if the theory is sound, it must be correct; but if false, it is no longer theory, but fancy. On the other hand, be it remembered that the farmer has sometimes to deal with wilful, stupid, and even unscrupulous fellow-men, with long-continued unfavourable weather, and frequent interruptions from various causes. These difficulties can only be met and disarmed by EXPERIENCE, or in other words, practical knowledge, and hence the vital importance of practice. The Royal Agricultural Society of England have adopted the motto, "Practice with Science," inculcating that while science must be guided and controlled by varying circumstances, practice must look to her for enlightenment and progress.

JOHN WRIGHTSON.

CIRENCESTER, *Feb.* 10, 1877.

CONTENTS.

PART I.

SOILS.

PART II.

MANURES.

SPECIAL MANURES.

PART III.

ROTATION OF CROPS.

PART IV.

LIVE STOCK.

SHEEP.

AGRICULTURE.

PART I.

SOILS.

In order to understand the nature of soils thoroughly, some knowledge of geology, mineralogy, chemistry, and physics, is necessary. Geology and mineralogy teach the origin, chemistry and physics the composition and functions of soils; and when these aspects have been studied, *climate* and all *surrounding conditions* must be taken into account before we can be in possession of full information.

The study of the soil is known as "Agronomy," but, from the foregoing remarks, it will be seen that agronomy is not in itself a science, but expresses the bearing of several recognised branches of science upon the study of soils.

Our subject may be usefully divided into the following sections: (1.) Origin, (2.) Formation, (3.) Distribution, (4.) Physical Properties and Surrounding Conditions, (5.) Classification, and (6.) Chemical Composition.

1. Origin of Soils.

As a primary fact, it may be stated that the entire mineral matter of soils has been derived from the gradual decay or disintegration of rocks. It is usual to state that soils are derived from the decay of the *crystalline* (primi-

tive) rocks, because from them all intermediate and newer rocks have been derived. The decay of a crystalline rock may yield a soil, or it may yield material which, by slow deposition in a deep sea, forms, in the course of long ages, a compact sedimentary rock. Such a sedimentary or stratified formation may, in process of time, be upheaved to the surface, and, under the influence of subaërial action, yield a soil still to be regarded as primarily derived from the original crystalline rock. Thus the chemical composition of the crystalline rocks becomes of high interest to the agricultural student.

This decay has been effected during the lapse of long ages by means of natural forces still in active operation, as may be seen in the crumbling of building stones, and that "weathering" which gradually changes the hardest rock into a powdery mass. Changes of *temperature*, operating with *water*, in the many forms assumed by that element, the action of the *atmosphere* and *vegetation*, are the chief causes of decay; and to these may be added *volcanic action*, which, as is well known, is the cause of the rapid formation of new and fertile lava soils.

In dry climates, where rain seldom falls, inscriptions upon stones retain their freshness for thousands of years, thereby proving the extreme durability of certain rocks when favourably situated. On the other hand, in a humid atmosphere, decay progresses much faster, as may be noticed in the crumbling condition of ruins, and even more recent buildings. During certain geological epochs, the surface of our planet has been exposed to conditions of heat and moisture highly favourable to the decay of rocks; and under those conditions, thick beds of granite, yielding to the influences brought to bear upon them, have been converted into sand and clay.

Composition of the Primitive Rocks.—In a short treatise like the present, it is impossible to enter minutely into the composition of rocks. But as the subject is closely related to the study of soils, I introduce an abridged table from the late Sir Charles Lyell's "Ele-

ments of Geology," giving the constituent parts of the principal minerals composing what are called the crystalline rocks. These are five in number, but being divided into species or varieties, the list is rendered more formidable. They consist of quartz and various kinds of felspar, mica, hornblende (amphibole), and augite (pyroxene), and to these must be added the zeolites.

QUARTZ is composed of silicic acid, and occurs in nature as exceedingly hard, and often transparent, six-sided crystals, or as masses of intensely hard rock. It is a constituent of all the crystalline rocks, and forms the entire mass of silicious sand.

FELSPAR is also very widely distributed, and is described chemically as an aluminium silicate with potassium, sodium, or calcium. For varieties, see table. The decay of felspar is the immediate cause of the formation of clay.

MICA.—The micas are aluminium silicates with potassium, magnesium, calcium, iron, and manganese. They readily split into thin plates of elastic texture and brilliant lustre, and are very widely distributed in rocks, or as micaceous shales and sands.

HORNBLENDE (AMPHIBOLE) AND AUGITE (PYROXENE) are magnesium and calcium silicates, or magnesium and ferrous silicates. They closely resemble each other, and are widely distributed minerals, of dark-green or black colour.

ZEOLITES are hydrated aluminium or calcium silicates, and an alkali. They are readily decomposed; and there is reason for believing that analogous compounds are formed in soils, and exert a considerable influence upon their properties. Zeolites occur in nature in a fine state of division, and also in crystals, and are found filling up the vesicular cavities and interstices of trappean rocks and ancient lavas (Lyell).

Analysis of Minerals most abundant in the Volcanic and Hypogene Rocks.

	Silica.	Alumina.	Iron Sesquioxide.	Ferrous and Manganese Oxide.	Lime.	Magnesia.	Potash.	Soda.	Specific Gravity.
Quartz, ...	100·0	..	..	..	..	..	..	..	2·6
The Felspar Group.									
Orthoclase.—Carlsbad, in granite (Bulk),	65·23	18·26	0·27	..	Trace.	..	14·66	1·45	2·55
—— Sanadine, Drachenfels, in trachyte (Rammelsberg), ...	65·87	18·53	..	..	0·95	0·39	10·32	8·42	
Albite.—Arendal, in granite (G. Rose), .	68·46	19·30	..	0·28	0·68	..	..	11·27	2·61
Oligoclase.—Ytterby, in granite (Berzelius), ...	61·55	23·80	..	..	3·18	0·80	0·38	9·67	2·65
—— Teneriffe, in trachyte (Deville), .	61·55	22·03	..	..	2·81	0·47	3·44	7·74	2·59
Labradorite.—Hitteroe, in Labrador rock (Waage), ...	51·39	29·42	2·90	..	9·44	0·87	1·10	5·63	2·72
—— Iceland, in volcanic (Damour), .	52·17	29·22	1·90	..	13·11	..	..	3·40	2·71
Anorthite.—Harzburg, in diorite (Streng),	45·37	34·81	0·59	..	16·52	0·83	0·40	1·45	2·74
—— Hecla, in volcanic (Waltershausen),	45·14	32·10	2·03	0·78	18·32	..	0·22	1·06	
The Mica Group.									
Muscovite.—Finland, in granite (Rose), .	46·36	36·80	4·53	..	..	..	9·22	..	2·90
Lepidolite.—Cornwall, in granite (Regnault), ...	52·40	26·80	..	1·50	..	..	9·14	..	2·90
Biotite.—Bodennais (V. Kobell), . .	40·86	15·13	13·00	..	..	22·00	8·83	..	2·70

BIOTITE.—Vesuvius, in volcanic (Chodnef),	40·91	17·71	11·02	..	0·30	19·04	9·96	..	2·75
PHLOGOPITE.—New York, in metam. limestone (Rammelsberg),	41·96	13·47	..	2·67	0·34	27·12	9·37	..	2·81
MARGARITE.—Nexos (Smith),	30·02	49·52	1·65	..	10·82	0·48	1·25		2·99
CHLORITE.—Dauphiny (Marignac),	26·88	17·52	29·76	..	..	13·84	..	..	2·87
REPIDOLITE.—Pyrenees (Delesse),	32·10	18·50	..	0·06	..	36·70	..	..	2·61
TALC.—Zillerthal (Delesse),	63·00	..	..	Trace.	..	33·60	..	..	2·68
THE AMPHIBOLE AND PYROXENE GROUP.									
TREMOLITE.—St Gothard (Rammelsberg),	58·55	..	..	..	13·90	26·63	..	..	2·93
ACTINOLITE.—Arendal, in granite (Rammelsberg),	56·77	0·97	..	5·88	13·56	21·48	..	..	3·02
HORNBLENDE.—Faymont, in diorite (Deville),	41·99	11·66	..	22·22	9·55	12·59	..	1·02	3·20
—— Etna, in volcanic (Waltershausen),	40·91	13·68	..	17·49	13·44	13·19	..	..	3·21
URALITE.—Ural (Rammelsberg),	50·75	5·65	..	17·27	11·59	12·28	..	..	3·14
AUGITE.—Bohemia, in dolerite (Rammelsberg),	51·12	3·38	0·95	8·08	23·54	12·82	..	..	3·36
—— Vesuvius, in lava of 1858 (Rammelsberg),	49·61	4·42	..	9·08	22·83	14·22	..	..	3·25
DIALLAGE.—Harz, in gabbro (Rammelsberg),	52·00	3·10	..	9·36	16·29	18·51	..	..	3·23
HYPERSTHENE.—Labrador, in Labrador rock (Damour),	51·36	0·37	..	22·59	3·09	21·31	..	..	3·30
THE OLIVINE GROUP.									
BRONZITE.—Greenland (V. Kobell),	58·00	1·33	11·14	..	..	29·06	..	..	3·20
OLIVINE.—Carlsbad, in basalt (Rammelsberg),	39·34	..	..	14·85	..	45·81	..	..	3·40
—— Mount Somma, in volcanic (Walmstedt),	49·03	0·18	..	15·74	..	44·22	..	..	3·33

The minerals whose composition is given in the above table, constitute the mass of the crystalline rocks, among which may be mentioned basalt, trachyte, porphyry, greenstone, and all members of the volcanic group. Also, granite, Syenite, gneiss, mica slate, and all Plutonic and metamorphic rocks.

2. Formation of Soils.

Bearing in mind what has been already advanced with reference to the general origin of soils, we have next to inquire somewhat more minutely into the processes which have at length resulted in their formation. The first destructive or disintegrating element which operates upon a rock is THE ATMOSPHERE, which is brought into closer contact with the rocky particles through the agency of moisture, in the form of snow, rain, dew, or mist. Through one or all of these forms of water, carbon dioxide is dissolved from the air which contains it, in the proportion of 4 in 10,000 parts. Thus the rock is brought into constant contact with a dilute solution of carbon dioxide in water. The action of this solution is slow, but irresistible when allowed to proceed through long periods of time; and under its action the hardest rocks, such as granite for example, yield up their alkalies, and some silica, the felspar loses its cohesion and falls into a soft powder (clay), while the quartzose constituents are left in the form of sand.

Changes of Temperature.—The foregoing effect is further expedited by changes of temperature, and especially by frost. Water expands as it freezes, and when water lodges in the interstices and pores of a porous rock, it suddenly expands as it congeals, and the consequence is a disruption of particles that speedily shows itself in the crumbling character of the rocky surface.

Vegetation.—As these forces proceed, a superficial layer of variable thickness is produced, and at an early stage vegetation exerts its sway. Lichens are seen

growing upon walls and the faces of quarries, and mosses and grasses follow at a later stage, and occupy the most unpromising situations. The effect is to increase moisture and to accumulate vegetable matter or humus, which again gives rise to carbon dioxide, and renders the rain still more potent in its dissolving and disintegrating action. The roots of plants also, no doubt, themselves exert a dissolving effect. Thus gradually a soil is formed, and it will bo noticed that, in this case, it is formed *in situ*, or upon the rock from which it was derived.

The forces still to notice differ from those already enumerated in their transporting effects, which, when added to their disintegrating action, renders them not only accountable for the origin, but the present position of many soils.

Action of Running Water.—Particles of sand or clay once detached from the parent rock are quickly carried away by the action of running water, and as these runnels gain strength and converge into mountain streams and torrents, a new manifestation of the power of water is exhibited in the wearing and undermining action which they invariably display. The attention of tourists on the Alps is often called to deep gorges, at the bottom of which is heard the gurgling of the stream. The wearing or cutting action is to be unmistakably traced through the compact rock from the top to the bottom of this gorge, in the water-worn hollows where the stream has evidently eddied and whirled at some remote period, sixty or eighty feet above its present bed.

Action of Rivers.—Mountain streams converge into rivers, which carry with them the mineral *débris* of the mountains, and distribute it over the plains beneath. All large rivers flow during a portion of their course through fertile alluvial plains; and further study shows that these plains have been deposited by the river itself, and are in fact composed of the mud brought from the higher grounds to be deposited at a lower level. As rivers widen towards their estuaries, they often deposit still more extensive

tracts of "alluvium" or mud. This is well exemplified in the case of the river Humber, which is the direct cause of large tracts of rich clay land in Holderness in south-east Yorkshire, and around Great Grimsby in Lincolnshire.

The Ganges in India, and the Mississippi in North America, both afford remarkable instances of the power exercised by rivers in altering the distribution of sea and land. In the latter case the mud, vegetable matter, and timber, brought down and deposited at and near the mouth of the river, is rapidly filling up the Gulf of Orleans. It is difficult to draw a distinction between the action of the sea and the action of the river in many of these cases, but both agents act in determining the direction of deposition.

Action of the Ocean.—Almost at any part of the coast traces of the perpetual struggle between sea and land may be seen. Upon the Northumberland, Durham, and North Yorkshire coasts, the sea is slowly encroaching, while in South Yorkshire and Lincolnshire the land encroaches on the sea. In Kent, the Isle of Sheppey is being slowly washed away, while in Romney Marsh we have an example of a comparatively newly-formed alluvial tract. The line from Yatton to Clevedon, in Somerset, runs over a flat tract of marine clay, surrounded farther inland by beautiful hills, which have evidently formed the coast-line at some distant period. Here is an instance of the acquisition of fresh land formed by the deposition of mud from the Bristol Channel.

Action of Ice.—The expansive force of freezing water as a means of breaking down rocks has been already noticed. Ice and frost also play an important part in the formation of soils upon a large scale. The grinding action of glaciers upon the sides of the ravines through which they slowly descend—for a glacier is not stationary, but is actually a river of ice—results in glacial mud, which, as the ice melts at the lower extremity, is carried down by the stream that perpetually runs from the glacier. These

streams are rendered milky or turbid by suspended matter, and it is only when they reach the level land at the base of the mountain that they deposit their burden in the form of alluvial soil. In many cases it is carried into a lake, and, sinking to the bottom, continues a process which, in the course of time, will gradually convert the lake itself into an alluvial tract.[1]

VOLCANIC ACTION.—It is well known that lava slowly crumbles into a fine fertile clay. The flanks of Vesuvius and Etna are clothed with vineyards and olive gardens, and the effects of volcanic action are observable in certain parts of our own country, where the active cause has long ceased to operate. Thus around Edinburgh there are fertile soils which overlie ancient fields of lava, and the same observation applies to certain districts in the north and extreme west of England. The formation of a soil from lava is effected, first by the rapid cooling of the surface of the molten stream, which speedily cracks into a cindery or scoriaceous porous mass, and this gradually yields to the influences of moisture and changes of temperature, and forms a soil.

PEAT.—There still remains a process by which a considerable class of soils has been formed, differing very widely from those which have been described. It is that of vegetation or growth. All peats have grown, and their history is sometimes traceable from its commencement. Peat soils occur only in moderate and high latitudes, but form an important class of cultivated soils in our own country, a very large proportion of Ireland—that country containing 2,800,000 acres of peat — and large tracts in France, Germany, Russia, and all north European countries. Peats frequently rest upon clay, and the

[1] It would not be advisable to enter at length into a description of the various great changes that the above forces have effected on the face of our planet. They have been noticed as active agents in the formation of soils, in order to give the student some insight into the nature of those forces to which the land he may be interested in owes its origin.—J. W.

history of their formation will be usually found to have been a modification of the following typical account.

A forest or tract of brushwood is overblown or levelled by some severe wind or flood. The consequence is an interruption of the natural drainage of the locality, and the inducement of a wet and spongy condition of soil favourable to the growth of many species of *sphagnum*. These plants have the property of throwing up new shoots while the lower extremities are decaying. Peaty matter also appears to be precipitated from water at the freezing-point, when organic matter held in solution falls to the bottom.

Indigenous (Sedentary) and Transported Soils.—We are now able to divide all soils into two great classes. First, those which may be said to be *in situ*, or to remain in the position where they were originally formed. As an example, take the thin white soils of the Upper Chalk which correspond closely in character with the compact chalk rock beneath. They are white, abound in flint-stones, and evidently belong to the Chalk, and are properly termed chalk soils. So also the clays of the Lias, of the Weald, and of the Oxford clay, the red soils of the New and Old Red Sandstone, and the "brashy" light soils of the Lower Oolite, all partake of the nature of the underlying rock, and are distinctly influenced by it. A large proportion of the soils of Great Britain are thus indigenous or sedentary, and rest upon the parent rock. Hence an important connection is at once evident between the geology and the agriculture of our country. The student is able to a certain extent to predicate the general character of a soil when he knows the main geological features of the district. He will expect to find open downs, or recently enclosed farms adapted for sheep husbandry, upon the Upper Chalk; and he will look for small fields and small farms, grass-land and cheese-making, bare fallows and orchards, when he finds himself in a district of Lias or Weald clay.

On the other hand, we cannot fail to observe that

over large tracts, the surface soil does not present any similarity of appearance or character when compared with the underlying rock. Here the surface soil has been TRANSPORTED from a distance. Sometimes it is superior in quality to what we might have expected, and in this case it is probably alluvial matter deposited by some river in its course or at its estuary; and there are cases in which the river that deposited these fertile plains has long ceased to flow. Or we may be standing upon an old lava field which covers and renders fertile an area that would otherwise have been comparatively barren.

At other times the soil is of lower quality than we thought to find, and in such cases its poverty may be due to the growth of peat or the accumulation of "drift." "Drifted" material masks, or covers, many localities in the Midland and other counties, giving a poorer soil than the underlying and masked rock would have yielded. A good example of this is to be seen in South Durham, east of Darlington, where a poor clay soil forms a district which, had it not been for a thick deposit of drift, would probably have partaken of the general fertility of the New Red Sandstone soils of North Yorkshire.

There are then two great classes of soils, the first bearing the stamp of its origin, and exhibiting a close relationship to the underlying rock, from which, indeed, it was formed.[1] In studying these soils, the main geological features of the country are exceedingly useful guides.

[1] In speaking of a soil resting say upon the Lower Oolite being derived from the underlying rock, it should not be forgotten that it is also partly derived from overlying rocks, removed by the process of "denudation." Thus, with the brashy soils of the Great Oolite, are intermixed the remains of the beds immediately above it, namely, the forest marble and its clays. Fragments of chalk and other indications of denuded formations once superimposed, are often observed upon the area under inspection. This fact does not, however, detract from the value of deductions as to the general character of a soil resting upon the Lower Oolite or any other formation.—J. W.

The second class comprises all alluvial, drifted, lava, and peaty soils, which, having been deposited, spread, or, in the last case, produced upon the spot at a later period, do not exhibit any correspondence with the main geological features of the district in which they occur. In these, minute geological study is requisite if we wish to trace their origin.

3. Distribution of Soils.

The bearings of geology upon agriculture are abundantly illustrated in the distribution of soils throughout England. It would be irrelevant to our subject to enter into the geological aspect of this subject at great length. The student who wishes to do so will find it necessary to study geology. It will, however, greatly assist him to grasp the plan of soil distribution if he keeps in memory the order of succession of the main beds or formations which constitute the explored crust of the earth, so far at least as England is concerned. The various strata which constitute England are superimposed upon each other in definite order.

The importance of this fact to the agriculturist is at once apparent, when we find that each *stratum in turn* occupies the *surface of the country*. It is the constant order of succession which makes the arrangement of the various formations of practical use to the land-valuer or the agriculturist.

The arrangement of the formations may be illustrated by a very simple device. A pack of cards may be used to represent the strata which concern us. When properly made and placed on the table, the topmost card may be supposed to represent the newest recognised geological formation. The card immediately beneath it will represent the stratum which underlies it. Each card in succession may be considered to represent an older rock, until we come to the bottom card, which may represent one of the primary or paleozoic groups. Place the pack

in a north-west and south-east direction, and then slide it in the latter direction, as in fig. 1, so as to discover the

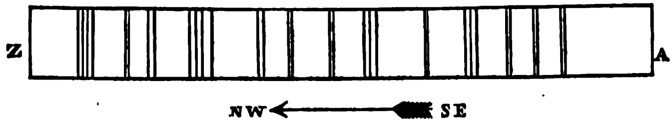

Fig. 1.

upper surfaces of a large number of cards, and a very correct idea of the manner in which the various geological formations occupy the surface of England is then obtained. A is the top card of the pack, and Z is the bottom card, and yet both are visible. If the hand is passed from A to Z along the extended pack, it must in turn traverse the exposed surface of each card until it arrives at the bottom one. Further, if, instead of looking from above down upon the pack, we look at the side elevation, it will be seen that the cards are no longer horizontal, but slightly tilted from north-west to south-east —they in fact dip to the south-east. The position of the cards may be used to illustrate the succession of various kinds of soils in England. Any one who travels across England in a westerly or north-westerly direction will pass over the various strata forming the surface in a very similar manner. All these strata dip towards the south-east, and all "crop" out towards the north-west. The succession and outcrop of the various strata are shown in the frontispiece section of the country from Hertford to Bridgewater.

The newer formations are on the south-east, and the older formations successively occupy the country until we arrive at the slates and flagstones of Wales, or the granite and gneiss of the Scotch Highlands. This, then, is the key to the succession of various kinds of soils in Britain. The student who wishes to pursue the subject further must procure a geological map, and with its assistance, trace out the various formations as they crop up to the surface usually in a line from north-east to south-west.

The accompanying list of the principal rocks from which our soils have been derived may be useful, and opposite each will be found a few remarks as to the general character of the agriculture, and of the land they support and yield.

Reference to the table will show that some geological formations yield soils of high average fertility, while others yield inferior soils. Some are stiff and expensive to work, while others are generally free working. It must, however, be remembered that geological knowledge, although useful, is not entirely to be relied upon. On all formations, good, bad, and indifferent soils are no doubt to be met with. The mingling of formations together at their edges, accumulation of drifted matter, the occurrence of less important strata, unnoticed perhaps in the geological chart, and other reasons, create numerous exceptions to any rule which may be laid down with respect to the soils of a certain geological formation. The subject is full of interest, and deserves a longer notice than we can at present afford it.

4. Physical Properties of Soils, and Surrounding Conditions.

The Proximate Constituents of Soils.—Soils differ widely from each other in their physical properties. Some are wet and consequently cold, while others are warm and dry; some are easily worked, while others are exceedingly tough; some are easily burnt up by drought, while others maintain a thriving herbage through the most trying seasons. The physical nature of a soil depends upon the proportion in which its proximate constituents are blended. All soils are composed of five proximate ingredients, namely: (1.) Sand, (2.) Clay, (3.) Lime, (4.) Vegetable matter, (5.) Mineral fragments (stones). Whether derived from the decay of chalk or sandstone, it will be found that all fertile soils are thus constituted, and the kind and quality of the soil depends

to a great extent upon the proportion in which these materials are mixed together. A short account of these familiar substances becomes therefore very necessary if we are to arrive at a sound conclusion regarding the nature of soils.

SAND may be either calcareous, micaceous, or silicious. A calcareous sand simply means a sand in which particles of lime, it may be shells, or chalk, abound. Many sea sands are of this nature, and may be applied to land as a source of lime. Pure sand is, however, free from lime, and consists almost exclusively of small grains of silicic acid (quartz). It is seen in the purest form as silver sand, and is accumulated in quantities wherever it is separated from earthy matter by the action of water. It is insoluble in water and acids, and fuses into a vitreous mass when subjected to a white heat. Sand quickly dries and possesses no power to absorb moisture from a damp atmosphere. A cubic foot of sand has been found able to hold 27 lbs. of water as a sponge, *i.e.*, without dripping. Its retentive power towards heat renders it useful in the chemical laboratory as a "sand bath," when it is required to keep up a uniform dry heat. Its insoluble, intractable, and simple or elementary characters render it unfit to support plant life. It cannot be said to be in any sense a plant food, but it acts as a divider or opener of the land. It facilitates the percolation of water through the soil; renders the passage of roots in search of food more easy; confers a degree of warmth on soils first by drying them, and secondly from its inherent power of retaining warmth; and renders the soil easy of tillage. All soils contain sand, and its greater or less predominence is used as a means of classifying them.

CLAY.—The purest forms are china or porcelain and pipe clays. In the first forms it is found in vast quantities, and becomes the basis of the manufacture of the finest white ware. It is plastic in its character, and to this property it owes its value as a material for making

bricks and pottery. The minute particles which form clay have been observed to be crystalline in structure.

When dry it may be reduced to an impalpable powder. When moistened it emits the characteristic argillaceous odour, and becomes highly plastic. When subjected to a low red heat it loses its plasticity, and becomes permanently hard and brittle—a fact of great importance not only in the arts but in agriculture. Clay is naturally colder than sand. In chemical language clay is hydrated *aluminium silicate*, but in nature it is almost invariably associated with potash, soda, lime, ferric oxide, magnesia, and carbon dioxide.

These impurities render clay much more valuable as a constituent of soils than if it were pure. It is in consequence of their presence that a clay soil is very often rich, and that clay ranks among the most important constituents of soils. Pure clay would be as little able to support vegetation as pure sand, but when associated with sand, native or impure clay yields a fertile soil. The special functions it performs in a soil are, first, the maintenance of fertility by the introduction of valuable mineral food constituents; secondly, clay gives "body" to a soil, by which is meant a certain consistency favourable to the retention of moisture; and coolness, which enables a soil to resist drought.

LIME is widely distributed, and occurs in vast quantities. The chalk hills which sweep through England from Flamborough Head to the Dorset coast, and from Salisbury Plain to Dover and Brighton, are almost pure lime. The Lower Oolite consists largely of lime, and the magnesian and mountain limestones cover large areas in the north and west. Lime is also found in the form of marls and marbles in many other geological formations, so that it is available for agricultural purposes in nearly all localities. It is employed as a manure in the forms of chalk, marl, and burnt lime, and its application and uses will occupy us when we consider the subject of manures. At present it appears before us as a constitu-

ent part of all fertile soils, and its wide distribution is illustrated by the fact that it invariably occurs in such soils in greater or less proportions. Although spoken of as "lime" by the farmer, it is more correctly described as calcium carbonate (carbonate of lime). The carbon dioxide is readily displaced, and flies off with brisk effervescence when any stronger acid is applied. Pure calcium carbonate is found in nature in the forms of Iceland spar, white marble, and chalk. When exposed to a red heat it parts with its carbon dioxide and water, and when cool it is found to be porous in texture, and to exhibit an avidity for moisture and carbon dioxide, which renders it caustic. It reabsorbs the water, and to a limited extent the carbon dioxide from the atmosphere, and as it does so, "slakes" or "falls" into a mild powdery mass. If water is poured over the calcined lime, the slaking is more rapid, and accompanied by the evolution of much sensible heat. The characteristic colour of lime is white. It is intermediate between sand and clay in tenacity and in its power of holding water.

Lime is an important constituent of all fertile soils. It is in itself a plant food, and a valuable manure. It exerts a strong effect upon decaying vegetable matter by accelerating its resolution into carbon dioxide, ammonia, and water; it also combines with vegetable acids, and forms with them neutral lime-salts, no longer injurious to vegetation. It plays an important part towards the mineral matter of the soil, by decomposing the silicates and setting free their alkalies. Lime acts mechanically by improving the texture of clay soils, and being of intermediate tenacity, it is also able to confer a higher degree of consistency upon light soils (see p. 101). Like clay, lime owes its agricultural value in a great degree to its impurities. Magnesian limestone, as its name implies, contains from 36 to 40 per cent. of magnesium carbonate, and about, or above, 50 per cent. of calcium carbonate. The limestones which form the Chalk, and the formations of mountain and oolitic limestones, are chiefly composed of the

latter salt; but associated with it there occur ferric oxide, phosphorus pentoxide, calcium sulphate, silica, water, and a trace of organic matter. Thus clay and native limestone will be seen to contain most of the elementary substances which enter into the composition of the ash of plants.

Vegetable Matter has accumulated in all cultivated soils, and in the form of peat it sometimes composes the entire mass. It is to the presence of humus or vegetable matter that the rich brown colour of good land is due. It may be described as a dark-brown, soft, porous substance, seen in the greatest purity in the form of well-rotted wood or leaf-mould. It is constantly in a state of decay or slow combustion, which is never completely arrested until it is reduced to the condition of pure carbon. The earlier agricultural chemists attributed a greater importance to this constituent of soils than is at present assigned to it. It was observed that all garden soils and fertile loams were rich in vegetable matter, and the inference was drawn that it was the cause of fertility. The late Baron Liebig, in his work on Agricultural Chemistry, published in 1840, demolished this theory by showing that humus was not the cause, but rather an inevitable consequence of richness. A rich soil, suitable for the growth of plants, cannot fail to accumulate vegetable matter by the fall of the leaf and the death of root fibres. A soil may be rich without humus, as is proved by the fertility of lava soils. The more a soil produces, the greater will be its stock of humus, as for example, in the case of a crop of mangel or swedes, or in the case of a hay or straw crop, the accumulation of roots in the soil leaves it positively richer in humus than it originally was, in spite of the many tons per acre of produce removed in the root crops. Land adapted for the growth of timber will yield many tons per acre of wood in the course of years, and yet the soil will be positively better stored with organic matter or humus at the end of the period than it was at the commencement. This can only be

explained on the ground that the carbon, hydrogen, and nitrogen, which constitute humus, are derived from the air and not from the soil. Although useful, it is therefore seen to be less essential than any of the proximate constituents yet noticed.

Humus is not assimilated directly by flowering plants. It is valuable as a perpetual source of carbon dioxide, and in a less degree as a source of nitrogen. The gradual decay of humus maintains the interstitial atmosphere, rich in carbon dioxide, and impregnates the rain which penetrates the soil with the same ingredient. It is in this manner that humus becomes useful in the nutrition of plants, and at the same time assists in that slow digestion which liberates insoluble matter from the soil, and renders it fit for the use of the plant. Humus is also highly valuable in modifying the texture of land. Without it a soil would be light in colour—powdery, dry, and harsh to the touch. With it it becomes brown in colour, cool, moist, and mellow, and in every way better fitted for the growth of plants.

Mineral Fragments (Stones).—Although stones might at first sight appear rather as intruders than as legitimate constituents of a soil, their constant occurrence and important uses lead us to consider them in the latter light. Their precise nature will depend upon the origin of the soil. Thus in an alluvial deposit or drifted soil we expect to find water-worn, round pebbles; in an oolitic limestone irregular fragments ploughed up from the rock beneath, and in a chalk soil we expect to find flints. They always modify the character of land when they occur in large numbers. Many soils now worked as light lands would be unworkable clays were they not lightened up and divided by countless stones. It is also important to bear in mind that stones may be regarded as undecayed fragments of the original rock from which the soil itself was derived. They are of all sizes, down to minute chips and particles, and especially must these smaller particles yield up fresh mineral food for plants under the influences

of frost, warmth, and moisture. A time must come in which even the largest will crumble down, and hence we may regard the mineral fragments as a magazine of mineral plant food.

A soil is then no mere mass of powdered rock, but a complex substance, the product of various forces, acting through long cycles, and modified by the growth of plants, and the decay of both vegetable and animal matter. Soils may be spoken of as the graveyard of countless generations of animated nature; as stocked with plant food at once available, and fortified with further as yet unprepared material, forthcoming when required.

In the language of a respected authority, it may be spoken of as a *laboratory*, in which beneficial changes are ever taking place, a *vehicle* by which plant food finds its way to the root fibres of growing vegetation, and a *storehouse* of present and future plant food.

The physical properties of soils will be modified according to the proportions in which sand, clay, lime, vegetable matters, and mineral fragments enter into their composition.

In order to possess fertility in the highest degree, a soil must afford easy access and egress to superfluous water, but at the same time must possess sufficient retentive power to guard against protracted drought; its texture must be at once firm and yielding, so as to afford protection to root fibres, while it allows of their free passage in search of nutriment; it should be well stocked with available plant food; and so situated with reference to subsoil and climate as to insure the realisation of the above good qualities.

POROSITY.—A fertile soil must be porous, *i.e.*, the particles which compose it must not be too near together, but allow room for an interstitial atmosphere, the free percolation and retention of water, and for the condensation of valuable fertilising matters upon the interstitial surfaces.

The porosity of soils is an exceedingly interesting sub-

ject. It occupied the attention of Jethro Tull early in the last century, and it afforded a fertile theme for investigation to the late Sir H. Thompson of Kirby, and subsequently to the late Baron Liebig, Professors Way and Voelcker, Mr Lawes, and other chemists. The porosity of a soil may be measured by the fineness of its particles. A coarse-grained sand, although more open in its texture, is in reality less porous than a finely-grained clay. It has *fewer* pores. Every time we break a fragment of any substance we increase the extent of its superficies, and this is practically true *ad infinitum;* so that an impalpable powder presents the largest possible surface, and is in a condition of maximum porosity. Our most porous soils are therefore our clays, a statement that is capable of satisfactory demonstration, although the use of the word in this connection would scarcely be accepted by agriculturists, who speak of sands as porous, in opposition to clays, which are spoken of as retentive soils.

The porosity of soils explains some of their most interesting physical functions. It is owing to this property that they are able to retain sufficient moisture for the use of growing vegetables. It is also owing to the same property, assisted by others, that soils are able to appropriate and hold certain valuable fertilising matters with sufficient strength to overcome the tendency of the rainfall to wash them beyond the reach of plants. That these important functions are possessed in the highest degree by clay soils, is sufficient proof that these soils possess the highest degree of porosity.

CAPILLARITY.—This property also depends upon porosity. It is observable that when a fluid is admitted between very closely contiguous surfaces, such as two plates of glass held almost touching, and dipped into water, the fluid will be seen to rise between the plates to a considerably higher level than its own. Lump-sugar and blotting-paper dipped into water are familiar examples of the same force; and a lump of clay, if immersed in a saucer of water, will become wet to its summit from the

same cause. The finer the interstitial spaces, the higher will the fluid ascend; and hence we find that a column of finely-powdered clay will become wet 36 inches above the surface of the water into which its base is dipped. Sand very quickly causes water to rise, but not higher than about 20 to 23 inches. Loamy soils will lift water by capillary attraction 35 or 36 inches; and lastly, clay broken into fragments as large as split-peas, only raises water 5·7, 9·5, and 12· inches high. These experiments upon the capillarity of soils were conducted by the author in glass tubes, filled with several kinds of soils in various conditions of fineness.

Capillarity is constantly exerted by soils, and the fact that it is continued from the deeper layers towards the surface during frost, accounts for the plashy condition of paths and roads when the thaw sets in. This subject will once more occupy us when we consider land drainage.

Influence of Porosity upon Fertility.—The influence of porosity upon the fertility of soils has already been alluded to. It has been long known that soil possesses strong deodorising power, and it can easily be shown to decolorise solutions and to transmit a colourless and odourless filtrate. Liquid manure, when filtered through a certain depth of earth, becomes thoroughly purified. It is this property of soil which makes it available for the purification of sewage, and in this case it is assisted by the oxidising influence of the air. After running over and through a sufficient area and section of land, sewage will be found to be perfectly colourless, and to have lost its offensive odour.

Further, it has been demonstrated by Professor Way and others, that watery solutions of ammonia, potash salts, and soluble phosphates, when filtered through ordinary soils, are robbed of almost the whole of these substances. They are held back by the soil in a state of physical or physico-chemical combination; and although capable of being once more partially detached by the

copious use of pure water, they are to a great extent permanently retained by the soil.

Thus the three most important fertilisers are found to be specially attracted to and held by the soil, a fact which bears upon the best means of applying such substances to the land.

This peculiar power seems to be due to a somewhat obscure adhesive force. It has been compared to the decolorising action of animal charcoal upon sugar, and also to the curious manifestation of adhesion or surface-attraction seen in dyeing. In this process particles of colouring matter are removed from solution or suspension, and become firmly fixed to the fabric, a common but not easily explainable phenomenon. In some such way the soil seems to remove colouring matter, smell, and even salts in solution from water, and to fix them in its pores or interstices.

It is also now certain that, as the forces already noticed (p. 14) detach fresh particles in a soluble form from the intractable and insoluble mass of the soil, that these particles will be fixed at once by the surface-attraction under consideration, and held safely for the use of plants. Thus available plant food accumulates in a fallow field or permanent pasture, and the ground becomes richer by rest.

Active and Dormant Constituents of Soils.—The preceding section will have shown that in every soil the material from which the tissues of plants may eventually be elaborated, exists in two physical conditions. First, there is the mass of earthy matter which has already been seen to consist of sand, clay, lime, vegetable matter, and stones; with the exception of lime none of these substances are taken up by the roots of plants. But associated with them in much smaller quantities are a number of substances (see p. 49) which constitute the active ingredients of a soil. Of these last a small portion is already soluble and available, and a larger quantity is insoluble, and therefore for the present unavailable.

The mass of the soil may be regarded as the hunting-ground in which the roots of plants ramify and search for food; also as a suitable material for preserving proper conditions relating to moisture and to temperature. It is indispensable to the well-being of the plant, but at the same time it is not the general mass of the soil which feeds it. The entire mass may be thus divided: First, the part comprising potential, or possible (future), plant food as yet insoluble in water and in acids. The second, the portion soluble in water, or dilute acid, representing the active or available plant food of the soil.

The available plant food is, unless removed, constantly recruited by the gradual decay of insoluble matter. It is acted upon by the forces enumerated in the section upon the origin of soils, and we find that the same forces which produced them are still acting upon them, and further effecting the disintegration of these mineral constituents.

What then is the nature of those changes which are for ever taking place in a soil?

By the removal of crops the available plant food becomes exhausted, and the field ceases to be productive. But after a few years of rest fertility is found to be restored. During the interval of rest the soil has been exposed to changes of temperature, to the action of air and moisture, and it may be to vegetative force in the action of roots of plants which have taken possession of the surface. The consequence is, that under the combined influences of these forces, fragments of quartz, felspar, apatite, phosphorite, gypsum, and other mineral substances, become "weathered." They part with small quantities of their substance, which pass over into the soluble and available condition, and thus a store of plant food once more accumulates.

This mineral matter rendered soluble will not be suffered to wash through the staple of the soil, but will be only carried a very short distance before it is seized upon and appropriated by that singular force of surface-attrac-

tion already noticed; and hence we see a satisfactory reason why "rest" restores land, and a clear difference between the *active* and the as yet dormant constituents of a soil.

Tenacity.—A degree of tenacity is essential to a soil. Where it does not exist in sufficient strength, the entire mass is liable to be gradually blown away. On the other hand, too great a tenacity causes a soil to be expensive and critical to cultivate, and unfits it for the growth of turnips, mangel, and other crops suitable for the winter feeding of stock. The tenacity of a soil is due to the presence of clay.

Slope or Inclination.—The slope of land is well

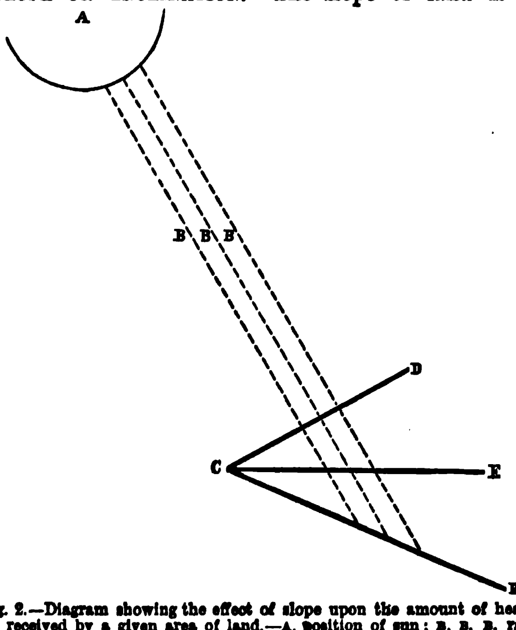

Fig. 2.—Diagram showing the effect of slope upon the amount of heat and light received by a given area of land.—A, position of sun; B, B, B, rays of light and heat; C D, the inclination of a field sloping towards the south; C E, a level field; C F, a field sloping towards the north.

known to influence its productive power, and that in more than one way. Slope to a great extent controls the drainage of water, and this alone must be allowed to be of first importance. It also admits of a greater or less intensity of light and heat upon a given area of the surface. If A represents the position of the sun, and B, B, B, rays of light and heat, it is evident that the plain of the surface upon which they fall must be most important in controlling the area over which they are scattered or distributed. Thus if the plain C D is at right angles to the direction of the rays, there will be no shadow, and the maximum of heat and light will be received on a square yard of surface. If, on the other hand, the plain lies at other than a right angle, as at E F, it will receive less light and heat, just in proportion as it so deviates.

It is from this cause that the north side of valleys, or those which enjoy a sunny or southern slope, are the most productive. It is upon such slopes that the finest wine is grown.

COLOUR.—Even colour influences the fertility of a soil, although to only a slight degree. A white soil, like white cloth, snow, or any other white substance, throws off the heat. On the other hand, dark-coloured substances absorb it.

A familiar illustration of this is seen in the fact that snow immediately underlying a piece of black cloth soon melts, while the surrounding snow, protected by its own whiteness, remains unaffected at the same temperature.

Subsoil.—A soil may be well stocked with plant food, and be of good physical character, but before it can be productive it must be provided with a proper subsoil. The reason of this is obvious, for upon the subsoil depends the drainage of the surface soil. A tenacious clay subsoil is by no means to be considered bad, but it will generally require to be thoroughly drained by artificial means before the superficial soil can grow abundant crops. A light sandy or gravelly subsoil secures the natural drainage of the surface, but is likely to cause it to burn or scorch in

droughty' weather. The effect of a rocky subsoil upon the cultivated surface depends upon the nature of the rock. A fissured dry rock like chalk is apt to give too dry a soil, while a cool porous stone, like that of the Old or New Red Sandstone, exerts an opposite effect. A rocky subsoil argues a thin soil and a low standard of fertility.

The term subsoil may be used to express the stratum which underlies the superficial earthy covering, irrespective of its depth beneath the surface, and in this case we might speak of a soil six feet thick underlaid by a subsoil of rock or clay. It is preferred at present to limit the term soil to the cultivated section. Subsoil is then made to express the section or zone which immediately underlies the plough-sole. By this use of the word, the term subsoil harmonises with the operation of subsoiling, which always refers to the breaking up of the section immediately under that usually cultivated.

Moor-band Pan.—In the reclamation of heath land a peculiar condition of subsoil is often met with, known as moor- or muir-band pan. It consists in the formation of an ochreous deposit a few inches beneath the surface, which resists the ordinary operation of ploughing, and requires to be broken up by a strong subsoiler drawn often by six horses. The cause of this hard concretionary floor, or pan, is the accumulation of salts of iron in the tissues of the heather. As these plants die and decompose, the iron, in the condition of ferrous salts, washes through the soil until it becomes further oxidised and insoluble, at which juncture it forms a cement with the earthy matters around it, and the consequence is the pan in question. When once broken up the pan never reforms.

Calcareous Pan.—Cases are on record in which, after a long period of shallow cultivation, a lime, or calcareous, pan is formed. It is well known that lime tends to sink through the land, and this tendency is most likely to be favoured by shallow cultivation. When a lime pan has formed, it must be broken up and mixed with the surface

soil, which will in all cases be greatly benefited, while the drainage of the field will be rendered more perfect.

INDURATED PAN.—The constant treading of horses and the passage of the plough-sole at one depth gradually indurates the bottom of the furrow to a mischievous extent, and forms a hard, beaten track, or pan, best removed by the adoption of deep cultivation, either by means of steam or horses.

Good cultivation is found to react upon the subsoil, and improve its texture and physical character. Thus liberal manuring, thorough drainage, and deep ploughing allow the access of air, and effect the pulverisation and aration of the subsoil. It changes in colour from a blue or black to a red, from the same cause as converts the dark venous blood into the bright arterial stream—the action of oxygen upon iron. This is followed by a true sweetening of the subsoil, caused by the complete decay of effete vegetable matter, and when this has taken place, the roots of plants strike deeper into the subsoil, and the consequence is a deepening of the staple and an improvement of the subsoil to a depth of several feet.

SUBSOILS WHICH EXERT A BENEFICIAL EFFECT ON THE SURFACE SOIL.—In alluvial soils, and where from any cause the subsoil is of similar character with the cultivated surface soil, deep tillage produces excellent results. To break up or disturb the subsoil is not by any means an operation to be promiscuously recommended, but in this case it may be followed without hesitation.

A light-topped soil, resting upon a retentive substratum, is on the whole to be considered a happy combination, although artificial drainage may be required to facilitate the percolation of water. In some cases the clay or marly subsoil may be dug up and spread upon the surface with good effect. A clay resting upon sand or gravel, if not of too open a character, is a good combination, as such soils are naturally drained. Here also mixing the surface soil and subsoil may be attended with good effects.

SUBSOILS WHICH EXERT AN INJURIOUS EFFECT ON THE

SURFACE SOIL.—All "pans," from whatever cause, are injurious, and require to be broken up. Happily this form of subsoil can be readily altered.

Open gravelly or rubbly subsoils are apt to allow fertilising matter applied to the land to wash through beyond the reach of the roots of plants. They are also liable to suffer from drought in hot seasons. Such land should never be manured in the autumn, but as much as possible during the period of active vegetation.

A rocky subsoil is usually objectionable, as preventing deep cultivation, and facilitating the escape of moisture too rapidly. Soils resting on the rock seldom carry heavy crops, but they are well adapted for sheep, and are usually farmed with a view to folding sheep in winter on roots, and growing barley.

Climate.—If to the possession of the previous characteristics of a good soil we can add a good climate, we shall have all the necessary conditions of fertility. The importance of climate cannot be overrated, for it is the immediate cause of the vast difference in productive power between a Tropical and an Arctic region. The term climate expresses three conditions, each of which is essential to the vegetative process—namely, light, heat, and moisture. These three conditions are all due to that energy which is constantly emanating from the sun, and hence vegetable life becomes more and more intensely active as the power of the sun increases, whether it be towards the equator, or towards that period of the year when the sun's action is most direct and long continued.

It is perhaps scarcely necessary to remind the student that the general character of the climate varies chiefly with latitude. If climate steadily improved as we travelled southward, and steadily became colder as we travelled north, the subject would have but little interest for agriculturists. This is, however, far from the case, for the climate of a country or locality is always considerably affected by various other circumstances besides that of latitude. To such an extent is this the case,

that probably every farm, and even field, boasts a particular climate, and practical farmers take climate into account when they are weighing the advantages or disadvantages of particular farms.

England lies in the same latitude as Moscow, and considerably higher than Newfoundland. The favourable climate which, despite adverse criticisms, we enjoy, is due to our insular position and the Gulf Stream, and, interesting as the subject is, we cannot further enlarge upon it here. Besides latitude, climate varies under the following circumstances: *Altitude, longitude, proximity to the sea, lakes, rivers, or marshes, aspect, character of the soil, and situation, as affected by shelter, slope, or inclination of the ground*, etc. Each of these circumstances exerts a marked effect upon the climate of a farm, and therefore upon its productive power.

ALTITUDE.—Wheat refuses to ripen in this country when grown at elevations of from 1000 to 1200 feet, a fact which proves the influence of altitude. An elevation of 1500 feet is sufficient to seriously impair the fertility of fields for even our hardier crops.

LONGITUDE.—The climate of Great Britain varies considerably in the matter of rainfall from east to west (see p. 70).

The heavier rainfall in the west of England is accounted for by the prevalence of westerly winds, which bring with them a constant importation of moisture from the Atlantic. Ireland receives the first benefit, and owes its title of the Emerald Isle to the abundant watering it receives from this cause. The high lands of Cornwall, Devonshire, Wales, and the Lake district of the north, also attract and condense clouds, and induce copious rains over all the west of the island. The highest recorded rainfall is at Seathwaite, Cumberland, where the total depth has reached 182½ inches in a year. The rainfall, and the soft western air, laden with watery vapour from the Atlantic Ocean, give a peculiar character to the climate of the west of England, contrasting some-

what favourably with the dryer and harsher air of the east. The effect on the agriculture of the two sides of the country is also easily seen in the prevalence of grazing on the west, and the leaning towards the cultivation of cereals on the east. The Gulf Stream also acts beneficially on the climate of the west both to the north and south of Ireland, which divides the current; Devonshire and Cornwall receiving additional warmth from its presence in the south, and Bute, Arran, and the south-west coast of Scotland on the north.

PROXIMITY TO THE SEA usually gives a more uniform temperature than is enjoyed far inland, and this is attributed to the uniform temperature of the adjacent mass of water.

LAKES AND MARSHES influence climate unfavourably. The latter especially often give rise to night fogs, which chill the ground and render the air unwholesome. An ordinary result is the prevalence of ague, and, it may be, certain forms of fever among the human population, and even the live stock of the farm are apt to suffer from allied ailments.

FORESTS.—The leaves of trees condense the atmospheric vapour, and precipitate it to the ground, as may often be noticed in a humid atmosphere. It is many years since Humboldt pointed out the effect of forests upon the supply of springs, and the consequent injury that may follow from their destruction. Hills clothed with wood offer a barrier to the descent of cold currents of air, and are also directly a shelter from the wind. The difference in temperature between a bare mountain and one which carries a forest on its higher slopes has been often remarked.

ASPECT is an exceedingly important element in influencing the climate. Who does not know the value of a southern aspect for wall-fruit, or of a northern aspect for a dairy? Such cases at once show that aspect exerts a decided influence. At page 33 attention was drawn to the effect of slope or inclination upon climate, and such

effect might have been included under the present heading. Aspect is, however, a wider term, and might include, as it certainly goes beyond, slope. The aspect of a house or a bedroom is a matter of importance, and so also is the aspect of a field.

Mr Bravender of Cirencester, in speaking of the elements of fertility, says: "Generally a south-eastern, south, south-western, or western aspect is a favourable indication; and a north-eastern, north, or north-western, unfavourable. Pasture lands having a northern aspect are more liable to be overrun with moss than those of the same quality of soil having a southern aspect."

Shelter.—Exposure or shelter must also be enumerated as a regulator of climate. An exposed situation is airy, breezy, or windy, according to the speed of aërial currents. It is often intensely cold, because the more rapidly a cold wind passes over any object, the quicker does it abstract its heat. Shelter, or protection from exposure, is highly valued, although in sultry weather we may long for the breezy unsheltered down or mountain side. Shelter is among the few climatic conditions which may be controlled, and hence a great deal of attention is given to it by agriculturists. A sheltered situation for house or homestead may be chosen, or trees may be planted, which in time will give what nature has denied.

There is also a larger sense in which the term shelter is applied, as when a range of mountains give shelter to a large district or fertile valley, conferring upon thousands of acres the advantages of an improved climate. A good example of this is seen in the fertile lands under the shelter of the chalk downs of Kent.

Character of the Soil is one more factor in the sum total of conditions which control climate. Any one may notice that the fog on an autumn evening hangs over a clay bed just as it hangs over a rock in mid-ocean. The cold nature of the clay ground first condenses the atmospheric vapour into a visible form. Delicate animals such as turkeys cannot be reared upon clay land, and

clay land districts are injurious to persons afflicted with weak lungs. On the other hand, a dry soil admitting of free drainage gives a warmer and dryer, and, in a word, a more wholesome atmosphere.

It is by modifying the character of land that drainage is considered to be a positive improver of climate. Artificial drainage causes water to quickly disappear beyond the influence of evaporation, and gives those advantages to a clay soil which are originally enjoyed only by those that are naturally drained.

INFLUENCE OF CLIMATE UPON THE PRODUCTIVE POWERS OF THE SOIL.—The importance of climate upon the fertility of soils can scarcely be overrated. It is seen not only in the different amount and character of the products of tropical and temperate countries, but also in the varying yield of our fields from year to year. A few facts bearing upon these points may perhaps be here introduced with advantage.

It is an ascertained fact that the period required to mature any crop varies with the climate. Wheat requires 92 days to grow and ripen at Venezuela, 100 days at Truxillo, 137 days in Alsace, 160 days near Paris, and 182 days in Scotland.[1] So completely does the period of growth and maturation depend upon the total amount of heat a crop receives, that the mean temperature of a wheat-growing country (taken during the period of growth) multiplied by the number of days required to perfect the crop, gives approximately the same numerical result. In other words, the total amount of heat required to perfect a crop of wheat is approximately the same:

	Period of Growth.	Average Temperature.
Thus at Venezuela,	92 days	× 75·6° = 6955°
,, Truxillo,	100 ,,	× 72·1° = 7210°
,, Alsace,	137 ,,	× 59·0° = 8083°
,, . Paris,	160 ,,	× 56·0° = 8960°
,, near Edinburgh,	182 ,,	× 47·4° = 8625°

[1] Stephens' "Book of the Farm."

It will be seen from the above numbers that in cooler countries, like France and Scotland, a larger amount of heat is required to mature the crop than in countries where the sun is more powerful. In Egypt, on the banks of the Nile, with a mean temperature of 70° F., barley requires only 90 days; and in South America maize comes to maturity in 92 days, with a mean temperature of 81·5° F. Examples might be multiplied, but it is unnecessary to do so, since those already given will sufficiently show that the productive power of the earth may be doubled by the quickening energy of powerful heat, for two crops in one season become a possibility.

Although in a less degree, many important differences in the kind, quantity, and quality of our own farm produce spring from the same cause. Altitude is often equivalent to latitude in its effect upon climate. If 56° F. may be taken as the mean temperature of a good vegetating season in Britain, say from 1st April to 30th September, an elevation of 590 feet will be equivalent to the loss of 1° on an average. Such situations are exposed to a greater range of temperature than lower and more sheltered places, owing to unchecked *radiation* during the night, and the consequence is an element of uncertainty, which from time to time involves the loss of a crop. The following facts relating to the effect of climate upon produce may serve to illustrate this point further:

(1.) English-grown wheat is inferior in quality to that from the south-east, Europe, and hot countries in general. It has been found that Indian sorts of wheat are relatively cheaper, compared with other qualities, and accordingly they have grown in demand, and advanced 2s. per quarter in the same week that some other qualities have lost ground (*Agricultural Gazette*, 2d Oct. 1876). (2.) The south-eastern counties of Essex and Kent have always been famous for growing remarkably fine samples of wheat, which must be considered due to their climate. (3.) White wheats can only be grown in favoured situations. On elevated tracts, or in the north of England,

red wheats are chiefly cultivated. (4.) In Northumberland 40 bushels per acre of wheat is considered a maximum crop; in the south, where the climate is more suitable, 50 and 60 bushels are often grown. (5.) Oats not only yield heavier average crops in the north of England and Scotland than in the south, but the quality of the Scotch oatmeal is allowed to be superior to that of the south. (6.) In hot countries the straw of all cereals is shorter, more brittle, and less nutritious than that grown in cooler countries. (7.) Swedes and turnips produce the heaviest crops, and are most nutritious when grown in a cool, moist climate. The turnip crops of Aberdeenshire far exceed, both in quantity and quality, those of the south of England. (8.) The climate of the south of England and the Midlands allows of a system of "catch-cropping" (see p. 146) which cannot be carried out to nearly the same extent in the north. (9.) A comparatively low summer temperature precludes the English farmer from the cultivation of the vine, sugar-beet, tobacco, etc., and confines him chiefly to the raising of grain and fodder crops. (10.) On the other hand, the cool and humid nature of our climate is the cause of our superior excellence in the production of beef, mutton, and wool.

5. Classification of Soils.

Sinking for a time the important consideration of chemical composition, the relative fertility of soils is largely due to the proportion in which the already described proximate constituents are combined. It is upon this principle that agriculturists classify soils, speaking of them as argillaceous, silicious, calcareous, or vegetable, according to the predominance of one or other of these substances.

The following classification was proposed nearly forty years ago by Schübler, and may be adopted as giving a method of distinguishing the various kinds of land. The terms usually employed by farmers in describing different

soils are numerous, but unfortunately either local in their significance, or the same term is made to convey a very different meaning in districts remote from each other.

SCHÜBLER'S CLASSIFICATION.—Schübler followed the method adopted by naturalists in dividing soils into classes, orders, species, and varieties. He recognised eight classes, based upon the predominating element of each.

FIRST, the argillaceous or clay group, containing always above 50 per cent. of clay.

This class he divided into clays without lime, and clays with from ·5 to 5 per cent. of lime; and these were again divided into poor, intermediate, and rich. Hence there were no fewer than six sorts of argillaceous soils: Poor, intermediate, and rich, with but little or no lime, and poor, intermediate, and rich, with a higher percentage of lime.

The SECOND CLASS is called "LOAMY SOILS," and contains from 30 to 50 per cent. of clay. Similarly these are divided into loams containing little or no lime, and those containing from 0·5 to 5 per cent. of lime, which again are each divided into poor, intermediate, and rich, making six sorts of loamy soils.

The THIRD CLASS is composed of SANDY LOAMS, containing from 20 to 30 per cent. of clay, and is divided into sandy loams with little or no lime, and sandy loams with from ·5 to 5 per cent. of that constituent. Here, as in the former classes, poor, intermediate, and rich soils are recognised with and without lime.

The FOURTH CLASS, designated LOAMY SANDS, contains from 10 to 20 per cent. of clay, and is divided into six species exactly on the principle just explained.

The FIFTH CLASS or SANDY SOILS contains under 10 per cent. of clay, and is also divided as above.

The SIXTH CLASS comprises all the marly soils. This term is only applied to soils which contain more than 5 but less than 20 per cent. of lime. Marls may be either argillaceous, loamy, of the nature of sandy loams, loamy sands, or of vegetable character, according as they coincide

in their proportions of clay and sand with the previous groups. Thus an argillaceous marl must have over 50 per cent. of clay, and from 5 to 20 per cent. of lime; and a loamy marl must contain 20 to 30 per cent. of clay, besides the requisite amount of lime.

The SEVENTH CLASS is termed CALCAREOUS, and contains above 20 per cent. of lime. This class again is divided into argillaceous, loamy, of the nature of sandy loam, loamy sand, or of vegetable character, as in the last case, and each of them is again divided into poor, intermediate, and rich.

In this class therefore we find poor calcareous clays, poor calcareous loams, and poor calcareous sands, or it may be intermediate or rich soils of each kind.

There are also pure calcareous soils, containing 94 to 98 per cent. of lime, and vegetable calcareous soils, divided into clayey, loamy, and sandy.

The EIGHTH and LAST CLASS deals with vegetable soils, or those which contain from 5 per cent. and upwards of humus, which are treated of as clayey, loamy, or sandy vegetable soils, according to the predominance of each of these elements. They are further divided according to the condition of the vegetable matter, which renders this class highly complicated.

Reference has been made to the division in each case into *poor*, *intermediate*, and *rich*. The test as to comparative richness was uniform throughout, and consisted in the proportion of vegetable matter. A poor soil of any class was a soil which contained from 0 to ·5 of vegetable matter; an intermediate soil must contain from ·5 to 1·5 of vegetable matter; and a rich soil must have from 1·5 to 5 per cent. of the same. Any proportion of humus exceeding 5 per cent., caused a transference of the soil into the class of humus or vegetable moulds.

In order to understand the foregoing remarks perfectly clearly, the accompanying table, extracted by the late Professor Daubeny, of Oxford, from Schübler's "Agricultural Chemistry," is introduced:

Classification of Soils (extracted, with a few Alterations, from Schübler's Work on Agricultural Chemistry).

Names of the different Descriptions of Soil.			Proportions of Ingredients in every 100 parts.			
Classes.	Orders.	Species.	Clay.	Lime.	Humus.	Sand.
1. Argillaceous Soils.	Without lime, or with lime, . .	Poor, . .	Above 50	None	0· to 0·5	Remainder.
		Intermediate,	„ 50	or	0·5 to 1·5	„
		Rich, . .	„ 50	0·5 to 5·0	1·5 to 5·0	„
2. Loamy Soils. Not more than 50 nor less than 30 per cent. of clay, . .	Without lime, or with lime, . .	Poor, . .	30 to 50	None	0· to 0·5	„
		Intermediate,	30 to 50	or	0·5 to 1·5	„
		Rich, . .	30 to 50	0·5 to 5·0	1·5 to 5·0	„
3. Sandy Loams. Not more than 30 nor less than 20 per cent. of clay, . .	Without lime, or with lime, . .	Poor, . .	20 to 30	None	0· to 0·5	„
		Intermediate,	20 to 30	or	0·5 to 1·5	„
		Rich, . .	20 to 30	0·5 to 5·0	1·5 to 5·0	„
4. Loamy Sands. Not more than 20 nor less than 10 per cent. of clay, . .	Without lime, or with lime, . .	Poor, . .	10 to 20	None	0· to 0·5	„
		Intermediate,	10 to 20	or	0·5 to 1·5	„
		Rich, . .	10 to 20	0·5 to 5·0	1·5 to 5·0	„
5. Sandy Soils. Not more than 10 per cent. of clay, ...	Without lime, or with lime, . .	Poor, . .	0· to 10	None	0· to 0·5	„
		Intermediate,	0· to 10	or	0·5 to 1·5	„
		Rich, . .	0· to 10	0·5 to 5·0	1·5 to 5·0	„
6. Marly Soils. More than 5, not more than 20 per cent. of lime, . . .	Argillaceous, . .	Poor, . .	Above 50	5 to 20	0· to 0·5	„
		Intermediate,	„ 50	5 to 20	0·5 to 1·5	„
		Rich, . .	„ 50	5 to 20	1·5 to 5·0	„
	Loamy, . . .	Poor, . .	30 to 50	5 to 20	0· to 0·5	„
		Intermediate,	30 to 50	5 to 20	0·5 to 1·5	„
		Rich, . .	30 to 50	5 to 20	1·5 to 5·0	„
	Belonging to the sandy loams, .	Poor, . .	20 to 30	5 to 20	0· to 0·5	„
		Intermediate,	20 to 30	5 to 20	0·5 to 1·5	„
		Rich, . .	20 to 30	5 to 20	1·5 to 5·0	„
	Belonging to the loamy sands,	Poor, . .	10 to 20	5 to 20	0· to 0·5	„
		Intermediate,	10 to 20	5 to 20	0·5 to 1·5	„
		Rich, . .	10 to 20	5 to 20	1·5 to 5·0	„

6. MARLY SOILS—*Continued.*	Humous, . . .	Clayey, . .	Above 50	5 to 20	Above 5·0	,,
		Loamy, . .	30 to 50	5 to 20	,, 5·0	,,
		Sandy, . .	20 to 30	5 to 20	,, 5·0	,,
7. CALCAREOUS SOILS. Containing more than 20 per cent. of lime, . . .	Argillaceous, . .	Poor, . .	Above 50	Above 20	0· to 0·5	,,
		Intermediate,	,, 50	,, 20	0·5 to 1·5	,,
		Rich, . .	,, 50	,, 20	1·5 to 5·0	,,
	Loamy, . . .	Poor, . .	30 to 50	Above 20	0· to 0·5	,,
		Intermediate,	30 to 50	,, 20	0·5 to 1·5	,,
		Rich, . .	30 to 50	,, 20	1·5 to 5·0	,,
	Belonging to the sandy loams, . .	Poor, . .	20 to 30	Above 20	0· to 0·5	,,
		Intermediate,	20 to 30	,, 20	0·5 to 1·5	,,
		Rich, . .	20 to 30	,, 20	1·5 to 5·0	,,
	Belonging to the loamy sands, .	Poor, . .	10 to 20	Above 20	0· to 0·5	,,
		Intermediate,	10 to 20	,, 20	0·5 to 1·5	,,
		Rich, . .	10 to 20	,, 20	1·5 to 5·0	,,
	Sandy, . . .	Poor, . .	0· to 10	Above 20	0· to 0·5	Any portion less than 80 per cent.
		Intermediate,	0· to 10	,, 20	0·5 to 1·5	
		Rich, . .	0· to 10	,, 20	1·5 to 5·0	
	Pure, . . .	Poor, . .	..	Above 99	0· to 0·5	None.
		Intermediate,	..	,, 98	0·5 to 1·5	None.
		Rich, . .	..	,, 94	1·5 to 5·0	None.
	Humous, . . .	Clayey, . .	Above 50	Above 20	Above 5·0	Remainder.
		Loamy, . .	30 to 50	,, 20	,, 5·0	,,
		Sandy, . .	20 to 30	,, 20	,, 5·0	,,
8. HUMOUS SOILS. Containing more than 5 per cent. of humus, . . .	Soluble mild humous,	Clayey, . .	Above 50	With or without lime.	Above 5·0	,,
		Loamy, . .	30 to 50		,, 5·0	,,
		Sandy, . .	20 to 30		,, 5·0	,,
	Insoluble carbonised or acid humus, .	Clayey, . .	Above 50	With or without lime.	Above 5·0	,,
		Loamy, . .	30 to 50		,, 5·0	,,
		Sandy, . .	20 to 30		,, 5·0	,,
	Insoluble fibrous vegetable matter, .	Bog and peat earth, .	With lime.		Above 5·0	,,
			Without lime.		,, 5·0	,,

6. Chemical Composition of Soils.

In studying the actual composition of soils, it must be remembered that the subject has a distinctly mechanical, or physical, as well as a chemical aspect. Chemical analysis teaches us the proportion in which the various constituents composing it are present. But how little light does this throw upon the *agricultural character* of a soil! We must know something of the *texture*, and the many important surrounding conditions already enumerated, as well as the ultimate composition; and hence inspection and a mechanical analysis should precede the more elaborate processes of the laboratory. The proportion of stones, gravel, gravelly sand, coarse sand, fine sand, clay, organic matter, and moisture, are ascertained by simple, but well-contrived, means.[1] To thoroughly understand the texture or mechanical nature of soils, their relations to heat and water must be taken into account, and when this has been done, the purely chemical analysis is rendered much more useful.

The chemical composition of the principal minerals composing the crystalline rocks has already been given (p. 10). The same component parts will naturally be found in all sedimentary rocks, although in widely differing proportions; and they will also be found to occur in all soils. The precise composition can only be discovered by analysis, but we may always infer that the leading constituent of a soil will be the same as that which gave character to the rock from which it was derived. Thus the silicious element will predominate in sandstone soils, the calcareous in chalks and limestones, and the argillaceous in soils derived from the great clay formations.

The only material of importance to be added to the list of constituents already referred to is organic matter, which is present in all soils as the result of the growth

[1] For full information upon both the mechanical and complete (chemical) analyses of soils, see "The Laboratory Guide," by A. H. Church, 3d edition (Van Voorst, 1874).

and death of plants. It is through the accumulation of vegetable matter in soils that they become rich in nitrogen in a state of combination available as plant food. But it must be remembered that the air is the ultimate source from which soils have derived their organic matter and nitrogen, and the process of slow combustion known as decay, steadily returns these materials back again to the air, or converts them into water and nitric acid.

A broad distinction is therefore drawn between the *fixed* or "inorganic" constituents of soils, and the organic substances which are in a perpetual state of change. Leaving the further consideration of humus, we must direct our attention to the mineral constituents of soils, which are also the constituents of the ash of plants.

The following substances occur in all soils, and in the ashes of all cultivated plants, and are also found to exist in the crystalline rocks.

Volcanic Rock Constituents.	Soil Constituents.	Ash Constituents.
Potash.	Potash.	Potash.
Soda.	Soda.	Soda.
Magnesia.	Magnesia.	Magnesia.
Lime.	Lime.	Lime.
Phosphorus.[1]	Phosphorus pentoxide.	Phosphorus pentoxide.
Sulphur.[2]	Sulphur teroxide.	Sulphur teroxide.
Silica.	Silica.	Silica.
......	Chlorine.	Chlorine.
Ferrous oxide.	Ferric oxide.	Iron.
Alumina.	Alumina.	......

Fluorine and manganese are also found to occur in many soils, in very small quantities.

The fertility of a soil must depend, among other things, upon the presence of every constituent required by plants, and so completely is this the case that the absence of

[1] Phosphorus occurs in small quantities in the oldest granite rocks.

[2] Sulphur occurs free in certain volcanic countries, and in the form of sulphides of the metals.

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even, what might appear, the least important substance, renders a soil unable to ripen crops.

In the above list those constituents which occur in least quantities in the soil are generally those which the ash contains in largest proportion, and are therefore most required by plants, and it is for this reason that potash and phosphorus pentoxide are highly valued as applications for land.

The constituents of soils occur in various conditions. It is not enough to know that a soil contains all the requisite materials for supplying ash constituents to plants, but we must know the state in which they exist. Hence a complete analysis of a soil should inform us as to the proportion of substances *soluble in water*, *soluble in acids*, and *insoluble in acids*. Taking as examples certain analyses of soils made by the late Dr Anderson of Glasgow, the relative proportions in which these three divisions occur may be approximately stated as follows:

	Midlothian.		Perthshire.	
	Soil.	Subsoil.	Soil.	Subsoil.
Substances soluble in water,	0·2319	0·2630	0·1191	0·2661
„ soluble in acids,	8·8600	6·5320	9·2156	10·8300
„ insoluble in acids,	78·2910	87·1210	79·3200	77·3590
Organic matters, . . .	12·7340	6·3800	11·1900	11·4020
Sum of all constituents, .	100·1169	100·2960	99·8447	99·8571

Each of the divisions in this table, with the exception of the last, contains all the mineral constituents of plants, and yet it must be evident that fertility must greatly depend upon there being a supply of substances soluble in water or dilute acids. That from 78 to 87 per cent. of

a soil, from which all pebbles and considerable fragments have been sifted, should be insoluble in acids, and therefore unavailable for present use, is itself a striking fact. Equally strange does it appear that ·1 to ·3 per cent. should represent the amount we may suppose to be readily available for solution. But although the percentage is small relatively, it is very considerable positively, amounting to from one to three tons per acre of ten inches in lepth.

The insoluble portion of soils must not be looked upon as useless. Not only is it the medium by which nourishment finds its way to the roots of plants, but owing to the continued action of the forces already noticed, a further disintegration is constantly taking place—a weathering action whereby fresh portions or particles of insoluble matter pass over into a soluble and available condition. The entire mass of a soil may then be divided into ACTIVE and DORMANT constituents (p. 31), the former class being constantly, although slowly, recruited from the latter. A soil which has borne successive crops of corn becomes exhausted of the active or immediately available ash constituents. A field exhausted in this sense, if allowed a period of rest, will be found to have regained its fertility, simply because fresh portions of mineral matter have been digested and reduced to a soluble condition. These considerations, therefore, show clearly that the large proportion of material in a soil, insoluble in acids, may be regarded as a *magazine* of mineral plant food, which will become available in the distant future.

The actual percentage composition of the soil is shown in the following analyses made by various eminent chemists. It is but seldom that a thorough analysis is made of all the divisions,—soluble in water, soluble in acids, and insoluble in acids. In the following examples the insoluble matter is lumped together as insoluble silicious matter. Table A shows the composition of a fertile alluvial soil from near the Zuider Zee, in Holland, analysed by Baumhauer, and in this

case, abstracted from Professor S. W. Johnson's excellent work, "How Crops Feed."

TABLE A.

TABLE SHOWING THE COMPOSITION OF A FERTILE ALLUVIAL SOIL from near the Zuider Zee, in Holland, analysed by Baumhauer.

	Surface.	15 in. deep.	30 in. deep.
Insoluble silica, quartz, .	57·646	51·706	55·372
Soluble silica, . . .	2·340	2·496	2·286
Alumina, ...	1·830	2·900	2·888
Ferric oxide, . . .	9·039	10·305	11·864
Ferrous oxide, . . .	0·350	0·563	0·200
Manganese oxide, . .	0·288	0·354	0·284
Lime, ...	4·092	5·096	2·480
Magnesia, ...	0·130	0·140	0·128
Potash, ...	1·026	1·430	1·521
Soda, ...	1·972	2·069	1·937
Ammonia,[1] . . .	0·060	0·078	0·075
Phosphorus pentoxide, .	0·466	0·324	0·478
Sulphur teroxide, . .	0·896	1·104	0·576
Carbon dioxide, . .	6·085	6·940	4·775
Chlorine, ...	1·240	1·302	1·418
Humic acid, . . .	2·798	3·991	3·428
Crenic acid, . . .	0·771	0·731	0·037
Apocrenic acid, . . .	0·107	0·160	0·152
Other organic matters, and combined water (nitrates?),	8·324	7·700	9·348
Loss in analysis, . .	0·540	0·611	0·753
	100·000	100·000	100·000

[1] The figures are probably too high for ammonia, because, at the time the analyses were made, the methods of estimating this substance in the soil had not been studied sufficiently, and the ammonia obtained was doubtless derived in great part from the decomposition of humus under the action of an alkali.

The following analyses of soils by Professor Church show the composition of a fairly fertile field upon the Royal Agricultural College farm, near Cirencester, and the subsoil of a tenacious clay field deficient in phosphorus pentoxide:

	Perfectly dry soil from No. 8 field, Agricultural College farm, Cirencester. Good wheat land resting on Forest Marble.	Perfectly dry subsoil from No. 4 field, Agricultural College farm, Cirencester. Stiff clay soil, resting on Forest Marble.
Organic matter and combined water,[1]	10·83	8·49
Oxide of iron and alumina,	16·00	16·88
Calcium carbonate,	12·51	4·54
Magnesia,	·77	·27
Phosphorus pentoxide,	·30	......
Potash,	·77	......
Potash and soda,	......	·29
Soluble silica,	......	1·27
Insoluble silicious matter (chiefly clay),	58·43	73·26
Other substances,	·09	......
Soda,	·10	......
	100·00	100·00

The following table represents the composition of various barren soils analysed by Dr Voelcker. Barrenness in these cases is due either to the lack of some constituent, or the presence of some deleterious substance:

[1] Containing nitrogen, ·45 = ammonia, ·544.

	Barren soil (dried at 212°) from Meare, near Bridgewater, abounding in organic matter and humic acid, and deficient in mineral matter, and especially so in phosphorus pentoxide.	Barren soil "poisoned by green vitriol," reclaimed from the sea on the Hampshire coast.	Completely sterile soil from Sandy, in Bedfordshire. Abounding in green vitriol and iron pyrites.	Composition of unproductive soils.				Poor Oxford *surface soil*. Clay-land pasture from Braydon Manor, Wilts, in which most of the "iron" present exists as protoxide.	Poor Oxford *subsoil*. Clay-land pasture from Braydon Manor, Wilts, in which most of the "iron" present exists as protoxide.
				Calcareous soil.	Sandy soil.	Clay soil.	Peaty soil.		
Moisture,	....	5·45	....	....	2·65	....	....	....	....
Organic matter & combined water,	97·760 [1]	9·93	4·27	....	4·56	7·94	49·07	15·13	7·43
Oxide of iron and alumina,	·536	7·18	3·84	·780	5·93	10·95	10·88	13·05	19·28
Calcium carbonate,	·855	....	....	73·807	·39	·86	2·29	....	....
Magnesia,	·144	·51	·96	·825	....	·26	·75	·26	·72
Potash,	·131	....	....	....	....	....	....	·56	1·39
Soda,	·065	....	....	....	....	....	....	·09	·14
Phosphorus pentoxide,	·053	....	·09	·242	....	·10	·06	....	·14
Sulphur teroxide,	·051	....	....	1·546	....	·30	1·04	·17	·08
Silica,	·405	....	....	16·710	86·19	....	....	....	....
Ferrous sulphate of iron (green vitriol),	....	1·39	1·05	....	....	....	....	....	....
Bi-sulphide of iron (iron pyrites),	....	·78	·56	....	....	....	....	....	....
Calcium sulphate,	....	·34	·85	....	....	....	....	....	....
Sodium chloride,	....	·04	....	....	....	....	....	....	....
Potash and soda,	....	·83	·47	traces.	·28	·39	·90	....	....
Lime,	....	....	....	....	....	....	....	·29	·40
Insoluble silicious matter,	....	73·55	87·91	6·090	....	79·20	35·01	70·45	70·45
	100·000	100·00	100·00	100·000	100·00	100·00	100·00	100·00	100·00

[1] Containing nitrogen, 1·428.

Means of Improving the Physical Character of Soils.

The physical character of soils may be modified by the following operations: (1.) Drainage, (2.) Subsoil and Trench Ploughing, (3.) Clay-burning, (4.) Claying, (5.) Marling, Chalking, and Mixing, (6.) Warping, (7.) Ordinary Cultivation.

Land Drainage.

The first place must be given to drainage, because of its vast importance, and because it ought to precede other methods of improvement.

Before capital in any form is applied to land it should be drained naturally or artificially, and hence it is evident that the drainage of land is of primary importance.

History of Land Drainage.—It is unnecessary to go minutely into the history of land drainage. The art of freeing land from water was well understood by the Phœnicians, Romans, and other nations of antiquity. The subject was thought of sufficient importance in Roman times to engage the attention of such eminent writers as Cato, Varro, Columella, Virgil, Pliny, and Palladius. The ancients were content with the work of reclamation, or the freeing of land which was under water or in a boggy condition. This gave occupation to improvers of land long before the idea occurred of freeing tillage or pasture lands from that surplus water which only prejudicially affects it at certain seasons of the year. The following extract from an able paper on agricultural drainage, by the late Mr T. Gisbourne, will convey an idea as to the progress of the art of drainage in this country:

"The earliest notice of English draining, which we have discovered, is contained in a broadside in vol. iv. of the 'Collection of Proclamations, etc.,' once belonging to James II., now in the library of the Society of Anti-

quaries, London. 'Herein,' says the writer, who dates from Paine's End, the 16th of November 1583, 'is taught, even for the capacity of the meanest, how to drain moores and all other wet grounds or bogges, and lay them dry for ever.' The draining for wet grounds is of a shallow order, and is illustrated by a herring-bone pattern. The main drains are to be filled with stones. The directions for executing them are as follows: 'Dig them one foote deepe at the least, and one foote broade in the bottome, and not above two inches broade at the top (*sic*), so will the top close up againe, and the bottome will be hollow'—'so shall you lose no ground. The charges for ten acres is 26s. 8d., besides carriages, which charges, the earth which you cart out of the ditch and drayners, being wel spred, wil countervail for the manuring of the ground.' The directions 'To draine Bogs' contain all we know at the present day. Our researches into agricultural literature made us acquainted with Walter Blith, 'a Lover of Ingenuity,' and Andrew Yarranton. Like other writers on husbandry, both published at a time of great agricultural depression, the former about 1640, the latter in 1677."

Passing over a long period in which the importance of draining was not appreciated by the public, although attention was from time to time called to the subject by various writers, we arrive at the year 1763, when Mr Elkington commenced the improvement of his farm of Princethorpe, in Warwickshire. Much of his land appears to have suffered from wetness, and it was in his efforts to remedy this defect that he discovered those principles of land drainage which have been adopted far and wide under the name of the "Elkington system."

After his own farm had been laid dry, Elkington continued to practise his art in all parts of England with great success, and in 1795 he received a reward of £1000 from Parliament, chiefly through the influence of Sir John Sinclair, at that time President of the Board of Agriculture. Mr Johnston, an Edinburgh surveyor, was also

appointed to draw up a description or report of Mr Elkington's system, which was published in 1797. Johnston did not derive great credit from the manner in which he performed his task, but it is only due to his memory to acknowledge that we should have known but little of Elkington's methods had he not preserved them to us. These methods are widely, but certainly not universally, applicable. Wherever an alternation of permeable and impervious beds occur, giving rise to springs, then Elkington's system may be carried out; but in homogeneous clay soils, or in any soil of uniform character wet from surface water or rainfall, the more regular plan advocated by Mr Smith of Deanstone must be employed.

Some idea of Elkington's method of draining will be obtained by studying the following woodcuts illustrative of his system.

Fig. 3 represents a condition of soil and subsoil favourable to Elkington's system. The tract F F, extending from B to D, is meant to represent a clay soil which requires draining. A A is a porous bed of sandy or gravelly character, which forms the surface above B, and then runs under F F until it terminates in a narrow point.

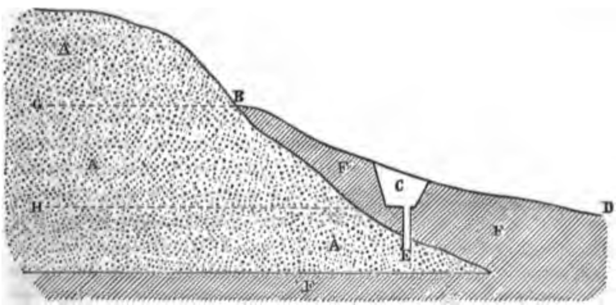

Fig. 3.

The retentive character of the clay prevents the downward percolation of the water which rises in A A, until

it bursts out as a spring at the point B. The whole tract B D then becomes wet, not only from the overflow of spring water, but the upward pressure of water which tends to ooze up through the clay from the gravel bed beneath. Under similar conditions did Elkington find his land to be wet when he commenced to drain it in 1764. His first effort was made in the usual manner, by digging a trench such as is represented at C. A simple trench could, however, exert but a small effect in drying a tract of land wet from a perennial source of bottom-water like that described. The flow of water disappointed him, and appeared disproportioned to the evident wetness of the situation. It is related that as Elkington was puzzling over his want of success, the shepherd passed with his iron bar, used in setting hurdles, over his shoulder. Elkington took the bar and struck it deeply into the bottom of the trench, causing the perforation C E. On withdrawing the bar up came the water, and continued to flow freely, resulting in the perfect success of the enterprise. A very little attention to the drawing will explain how the shepherd's bar came to act so "miraculously." The line G B represented the level at which the water stood in the gravel previous to the successful drainage of the tract B D. An ordinary trench, such as that at C, could not influence the mass of water lying immediately under it, until the happy thought occurred to Mr Elkington of trying the auger. This happened to strike the tail of the water-bearing stratum; and since water rises to its own level, there was an immediate rush of water, which would continue until the water-level was reduced to the height H C, and the land above that level was thoroughly freed from wet. Fig. 4 illustrates Elkington's principle in another manner, although the principle is essentially the same. B B represents a pocket, or basin of clay soil to some extent pervious, surrounded and underlaid by a gravelly formation, in which water has accumulated. The rainfall on the surfaces G G has settled down into the hollow, and must be supposed to

be held up by a second retentive formation beneath. Under these circumstances the level of the water is capable of rising up to F F, at which points it will issue

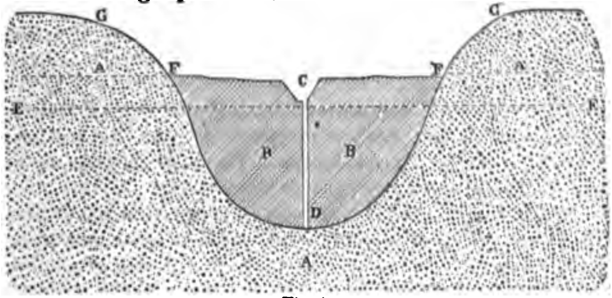

Fig. 4.

forth as springs, and wet the entire surface. The upward pressure will act at the same time, and the consequence will be that the tract of clay land will be useless for agricultural purposes. Here again a simple trench, dug across the wet land, as at C, would be of no avail. The source of water must be reached; and if a bore-hole were sunk through the clay down to the sand, as represented in the figure, the water would rush up and continue to flow until its level was reduced to the line E E.

The next great impetus to land drainage was given by the late Mr William Smith of Deanstone, Perth, who in 1836 was examined as a witness before the "Agricultural Committee." "He gave a detailed account of his system of draining, which very much resembles the furrow-draining of the Midland counties of England, except that at Deanstone, stone being on the ground, the drains are made with stones and not with tiles; and at Deanstone the cover of the drain is 22 inches below the surface, whereas in Leicestershire and Northamptonshire the top of the tile in the furrow is not so deeply laid."[1]

[1] "On the Deanstone Frequent Drain System," by the Hon. Sir James Graham. R. A. S. Journal, vol. i., 1839.

In 1843 Mr Pusey published a paper on "Thorough Draining," in which he described a cylindrical or pipe tile, used by a Mr Hammond of Penshurst, in Kent; and when this simple underground channel came into general use, in combination with Mr Smith's parallel system, the system of drainage now in general use may be said to have been perfected.

Mr Smith's method differed from Elkington's in its regularity, the entire surface of the field being divided into parallel panes by furrow-drains. These flowed into main drains, which carried off the surplus water.

THEORY OF LAND DRAINAGE.—It appears somewhat paradoxical that drainage should be beneficial to vegetation. Water is so essential to the well-being of plants, the value of irrigation is so well known, and the "oasis" so familiar a metaphor, that the advantage of robbing land of its water seems a little questionable. To settle all doubt upon this point, we may at once state that such is not the drainer's object. More water passes through a drained than through an undrained soil, and the following remark of a veteran agriculturist on this very point is perfectly true.

A party of gentlemen were throwing doubts upon the advantage of draining a particular clay field. "Look," they said, "what is the use of draining such land as this —not a drop of water is running from the pipes." The reply was sagacious: "*I don't drain so much to get water out of the land as to get it into the land.*" Such is the fact. The work of the drainer consists in giving a free passage to water, thereby securing the passage of the entire rainfall through the body of the soil. It must be evident that, of a yearly rainfall, say of 28 inches upon a tenacious and wet (undrained) piece of land, part soaks into and through the soil, part finds its way as best it can into ditches, and part starves the soil by its evaporation once more into the air. But on a drained field, which is never surcharged at the surface, the whole of the rainfall passes into the land, thus proving the truth of the remark just quoted.

By following out the above idea, a flood of light is thrown upon the subject of drainage. Undrained land is surcharged with water for a great part of the year. By this is meant that the pores, or interstices, of the soil are completely full of water; and since two materials cannot occupy the same space in the same time, it is evident that, while this state of things exists, neither fresh water nor air can gain admittance. The land is full of water, but it is STAGNANT or stationary. After drainage, the land may still be full of water at times, but it is in a condition of movement. The contrast between water in a stagnant and moving condition is striking, as the following considerations will show. Stagnant water has done its work, and now plays the part of the dog in the manger, neither moving on itself nor yet allowing the ingress of fertilising showers and air.

INJURIOUS ACTION OF STAGNANT WATER.—Stagnant water acts injuriously by lowering the temperature of soils by surface evaporation. The most elementary knowledge of physics reveals the fact that a liquid cannot be volatilised without absorbing, and rendering latent, a large quantity of heat. Conversely, gases cannot be condensed without developing a large amount of sensible heat. When water is once raised to the boiling point, it cannot by ordinary means be made to rise in temperature beyond the 212° of Fahrenheit's scale, or the more convenient 100° Centigrade, which represents the same temperature. All the heat communicated to the vessel from the fire is, after the point of ebullition has been reached, employed in converting water into steam, and yet the steam will be found to emerge at the same temperature as the water. Now it is important to bear in mind that evaporation takes place at low as well as high temperatures. To evaporate 1 lb. of water at any pressure or temperature, the same amount of heat will be required, and hence the application of this fact to the condition of a wet field will be at once apparent. The late Mr Josiah Parkes, for many years consulting

engineer to the Royal Agricultural Society, estimated that to evaporate 30 inches of rainfall, would require heat equivalent to the burning of 1 cwt. of coal per acre per hour throughout the entire year! This gives a tangible idea as to the vast amount of heat which must be abstracted from land in a state of aqueous repletion and stagnation. In order to practically test the actual difference in temperature between drained and undrained soil, Mr Parkes instituted an elaborate experiment with thermometers, plunged at various depths, from 7 to 31 inches, in Red Moss, near Bolton-le-Moors, Lancashire. The temperatures were taken in the natural bog, and in the drained and reclaimed portion of the bog, with the general result that 10° F. was gained in temperature at 7 inches in depth in the drained land. Also, while the uniform temperature of the natural bog was constant at 46° at from 1 to 30 feet depth, the temperature of the drained land ranged from 60° at 7 inches deep, to 48° at 31 inches, showing that even at a considerable depth a higher temperature was gained.

The above paragraph sufficiently shows the injurious effect of stagnant water, but there are other ways in which its baneful effects are manifested.

Water is a bad conductor of heat, although, owing to the mobility of its particles, warmth as usually applied is quickly disseminated throughout its mass. If water be heated from below, the particles which first receive the heat become specifically lighter than those above them, and rise towards the surface. Simultaneously other colder particles descend, and in turn become warm, and rise also to the top. This constant circulation of particles tends to keep the entire mass of water at a uniform heat, until all is raised to the boiling point at the same moment. If, however, the heat is applied at the top it will be found to descend very slowly indeed by actual conduction from particle to particle. Hence, water is considered to be a bad conductor of heat, and, apart from its removing heat by evaporation, an excess of water must

prevent a soil from receiving a due share of the sun's warmth.

Water, if a bad conductor, is an excellent radiator of heat, as is shown by the rapidity with which it cools. A soil wet up to the surface will therefore cool rapidly by radiation, and if, as will probably be the case during the wet months of the year, it is saturated with water throughout its staple, we shall find the cooling process further assisted by convexion. Supposing the uppermost film of water to be cooled by evaporation and radiation, it will become heavier and sink through the soil, while its place will be taken by warmer and specifically lighter water from the lower sections of the soil. Hence an injurious interchange of particles will be established by a current of cold water downwards, and warmer water upwards, which will only cease when the entire mass congeals.

It will be seen from the above remarks that stagnant water acts injuriously by lowering the temperature of soils, and that in several ways. It not only acts *positively* to the detriment of land as just described, but *negatively*, by preventing the beneficial action of air and rain. These considerations will occupy us immediately, but before quitting the subject of the directly injurious action of stagnant water, there is one more point which demands attention. It is the mechanical injury done at the surface by the overflow of water. When water cannot pass through the soil, it finds its way as best it can to the ditches, from whence it is emptied into the rivulets, brooks, and becks, which together with rivers constitute the natural drainage system of the country. In its passage it carries with it the finer particles of soil and much valuable fertilising matter in solution. After heavy rains the field is seen to be much washed, the sandy particles being left in the water-courses, while the finer particles of clay are deposited at a greater distance, to the great detriment of the soil.

Beneficial Action of Water in a State of Motion. —All the evils due to stagnant water are got rid of when

once thorough drainage has been effected. Water when in a state of motion also exerts the following positive benefits: (1.) It directly conveys warmth to the soil and subsoil; for although in winter the temperature of the rain may be below that of the ground on which it falls, yet in the period of active vegetation it is several degrees warmer. Mr Parkes found the temperature of rain during a thunderstorm in June to be equal to that of the air, namely, 78°, while the temperature of the soil was 62½°, 7 inches deep, and 50° at a depth of 2 feet. Under similar circumstances the passage of freshly-fallen water through the soil must convey direct warmth to the roots of plants. (2.) Rain water carries traces of carbon dioxide, ammonia, and nitric acid, with it, which it has washed out of the air during its fall. These substances no doubt exert a beneficial effect, partly because their presence heightens the solvent action of water upon the mineral constituents of the soil, and also because they increase the nutritive value of water as a plant food. According to Way, the total quantity of nitrogen in the form of ammonia and nitric acid, brought down by rain and snow upon an acre of land in the year, was found to be 6·63 lbs. in 1855, and 8·31 lbs. in 1856. To this must be added a small quantity deposited in dew and fogs, which has not been estimated.

The advantages of water in a state of motion were thus graphically described by the late Baron Liebig ("Natural Laws of Husbandry," Dr Blythe's translation): "It is well known that stagnant water in the soil is injurious to most of the cultivated plants; and the favourable effect upon their growth produced by draining just depends on this, that an outlet is opened to the water moving by the force of its own gravity, and the earth is moistened by that water only which is retained by capillary attraction. If we regard the porous earth as a system of capillary tubes, the condition which must render them best suited for the growth of plants is unquestionably this, that the narrow capillary spaces should be filled with water, the wide

spaces with air, and that all of them should be accessible to the atmosphere. In a moist soil of the kind affording free access to atmospheric air, the absorbent root fibres are in most intimate contact with the earthy particles; the outer surface of the root fibres may here be supposed to form the one, the porous earthy particles the other wall of a capillary vessel, the connection between them being effected by an exceedingly thin layer of water."

EFFECT OF ALTERNATE CONTRACTION AND EXPANSION ON DRAINED SOILS.—A wet soil is almost always in a sodden or water-logged condition, while a drained soil is repeatedly wet and quickly dry. Accompanying and depending upon this alternation of condition, a drained soil contracts as it dries, and expands when it is once more wetted with rain. Any one who has observed the cracks that appear in land after a severe drought, and which close up again after rain, will understand that in a drained soil there must be an alternate contraction and expansion induced throughout the soil.[1] Not only will there be large cracks formed, but small ones, and the entire soil will be fissured in every direction. As a consequence, the soil becomes pulverised to a considerable depth, and both soil and subsoil are benefited. This pulverising action proceeds slowly, and accounts for the fact that land drainage does not operate fully the first season, but requires several years before its advantages are realised.

[1] I had the opportunity of seeing a good instance of contraction of a clay soil after drought in August '76, upon the College farm, Cirencester, after a long continuance of dry weather. The cracks formed a network over the field, especially in the stiffest portions, and in many, a walking-stick could be buried in them when thrust down vertically. As the ground was seldom cracked straight downwards, this test could scarcely be considered sufficient to prove the depth of the fissures, which probably extended from 4 to 5 feet deep. When we take into account the numerous smaller cracks, which without doubt formed a network to a considerable depth through the soil, and remember that every crevice is a channel for air to enter, we need not wonder at the beneficial effects of alternate contraction and expansion.—J. W.

Root Action.—When land is drained the roots of plants penetrate to depths which they were formerly unable to reach. Schubart caused an excavation to be made in the field "to the depth of 6 feet, and a stream of water was directed against the vertical wall of soil until it was washed away, so that the roots of the plants growing in it were laid bare. The roots thus exposed in a field of rye, in one of beans, and in a bed of garden peas, presented the appearance of a mat or felt of white fibres, to a depth of about 4 feet from the surface of the ground." The same investigator traced the roots of winter wheat 7 feet in depth in a light subsoil forty-seven days after sowing. Colza and clover roots were also found to be from 3 to 4 feet long.[1]

It is evident, therefore, that we must add *vegetation* to the causes already enumerated, if we would thoroughly account for the benefits of thorough drainage upon the subsoil. That the subsoil is changed in colour and texture to a remarkable extent when brought under the influence of vegetation, has been proved at Rothamsted, and is demonstrated there by means of excellent specimens of soil and subsoil preserved in the laboratory in large glass jars.[2]

Beneficial Action of Air.—When water freely sinks through a soil, *air must follow*. If it did not, a vacuum would be formed, which, with an atmospheric pressure of 15 lbs. to the square inch, is quite impossible. Hence the motion of water through the soil is a guarantee that air also finds its way there. The result is the gradual decay, or slow combustion, of vegetable matter, which, when oxygen is deficient in quantity, forms sour and injurious products. Partial decay gives intermediate and often acid products, but complete decay results in the evolution of carbon dioxide and ammonia, both of which are appropriated by plants. The carbon dioxide also acts upon the

[1] "How Crops Grow," pp. 232, 233.

[2] See also Mr Lawes' valuable paper on "Drought of 1870," series ii., vol. vii., *Journal of the Royal Agricultural Society*, 1871.

mineral constituents of the soil, and assists to bring them into an available condition for plants. Oxygen changes the condition of the ferrous oxide, which occurs in undrained soils, into the ferric or higher oxide. This peroxide, familiarly known as iron rust, gives the characteristic red colour to clay. It readily parts with a portion of its oxygen to growing or decaying vegetables, and once more recoups itself from the oxygen of the air when air is freely admitted. Thus the iron in the soil plays the part of a carrier of oxygen, giving up its less tightly held oxygen to the more pressing demands of vegetable growth or decomposition, but always reabsorbing its lost oxygen from the air. When a sufficient supply of oxygen is not present, the sulphates or salts of sulphur teroxide are, simultaneously with the ferric oxides, reduced to a lower state of oxidation, and form iron sulphuret or sulphide, which is known to be most injurious to vegetation.

PRACTICAL BENEFITS DUE TO LAND DRAINAGE.—We have hitherto considered the theoretical reasons why land drainage is beneficial. It has been shown that, so far from robbing the soil of that indispensable substance water, the benefit of drainage is due to the complete realisation of the rainfall. The practical advantages which naturally spring out of the explanations already given will be almost anticipated. Taking the case of a soil in which the stagnant condition of the water has been converted into a condition of movement, it will be found that the following substantial advantages are reaped:

1. *An earlier Harvest.*—In some cases drainage has made a difference of a fortnight in the ripening of corn crops. An early harvest is certainly an advantage, especially in the north, where a late harvest is apt to be interrupted by bad weather. An early harvest also gives facilities for the autumn cultivation of stubbles, and for the sowing of stubble crops.

2. *A more abundant Harvest.*—This is a general result of land drainage. In some cases the entire yield may be said to be due to the operation. Where ordinary

tillage lands have been well drained, the advantage has, in many cases, been estimated at 8 bushels of wheat per acre.

3. *A better quality of Produce.*—A more wholesome condition of soil naturally causes a more perfect development of the plant. Thus longer straw and better filled ears are only what might be expected. The plant is better able to resist the insidious attacks of disease, and does not so readily fall a victim to mildew, rust, and other fungoid attacks, commonly known as "blights."

4. *A greater variety of Crops.*—On undrained soils, and especially on wet clays, the farmer rarely ventures upon sowing a large variety of crops. He is compelled to allow a proportion of his land to lie idle as "bare fallow," and the remainder will be occupied by wheat, oats, beans, and a little clover. After thorough drainage, the same land may be made to grow a much larger variety of cultivated plants, such as swedes, turnips, mangel, kohl-rabi, cabbages, vetches, besides the cereals, and a much better and surer plant of clover. It must not, however, be thought that the character of the land is entirely changed by drainage. It is altered and improved; but a clay soil will always be critical to manage even after thorough drainage, and the degree of improvement will be found to be very various.

5. *Tillage rendered easier and less expensive.*—This is an important advantage, springing naturally out of the explanations already given. It is also due to the increase in the number of working days during the year upon drained land. On wet clay soils the farmer must wait for his land to dry. Nothing is more injurious than to attempt to work clay land when wet, and the time so spent is considered to be worse than wasted. Since drainage greatly shortens the period required to dry land, the number of working days throughout the year is considerably increased, and that strain upon the horses of the farm, so common at favourable seasons upon clay lands, is avoided. Either, then, fewer horses will be required, or those

which are kept will be maintained in working condition at less cost.

6. *Applications of Manure more effective.*—There can be no greater mistake made than that of applying fertilisers, in any form whatsoever, to wet land, and this is one of the best reasons for insisting upon thorough drainage as a first step towards improvement. Neither oil-cake given to live stock, lime applied to the land, or top-dressings distributed over growing crops, will yield satisfactory results upon undrained wet soils, but after drainage all these means may be used with advantage.

7. *Health of Live Stock improved.*—Certain diseases are constantly associated with the presence of stagnant water. Although it would scarcely be correct to speak of stagnant water as directly causing black-leg and red-water among cattle, or "rot" among sheep, yet there can be no doubt that a wet condition of soil induces the presence of the active causes of these diseases, and that thorough drainage tends to extirpate them.

8. *The health of the rural population* has also been greatly improved in many districts where drainage works have been carried out on a large scale, and this alone is a sufficient reason for viewing the operation as of national importance.

The solid advantages just enumerated are quite sufficient to account for the high value set upon drainage by the practical farmer. Special facilities have been granted by Parliament to enable landlords to raise money for this purpose, and tenants, as a rule, are willing to pay 5 per cent. upon money expended in draining their land.

Theory of Drainage—*Continued.*

Sources of Water—Water Economy of Soils.—The rainfall is the primary cause of wetness in land, and when it proceeds entirely and directly from rain, land is said to be wet from "*surface water.*" Land is also often wet from "springs" which draw their supply from lands at a

higher level, and subsequently pour it over the surface at a lower level. In other cases land is wet owing to the soaking of water from higher levels through a porous stratum, and again appearing at the lower level, not, strictly speaking, as a spring, but pressing up diffusively, and hence called "diffluent" water. It was in the draining of lands wet from this "bottom water," as it has been called, that Elkington achieved his reputation. Attention has already been called to the importance of dealing with "effluent" and "diffluent" water (p. 57), and in all drainage plans means for their removal should be provided. While, therefore, some soils are wet from inability to get rid of the annual rainfall, others are wet from *position* only; and while some soils are self-drained and enjoy all the many advantages of *percolation*, it not unfrequently happens that they transmit their water, much to the detriment of lower lands.

THE RAINFALL.—Assuming 25 inches to represent the average depth of rain which annually falls upon every acre of land, we have 2532 tons, or 567,168 gallons, of water to deal with. Although these amounts may be useful as bases for general calculations, they by no means give a correct idea as to the amount of rain which falls in various and distant parts of the country. The rainfall is greatest on the west, and least on the east side of Great Britain. The following average amounts have been registered at various meteorological stations upon the west and east respectively:

West.		East.	
In Cornwall,	38 in.	In Suffolk,	23½ in.
,, Gloucester,	30 ,,	,, Middlesex,	25 ,,
,, Lancashire,	34 ,,	,, Nottingham,	25 ,,
,, Bute,	38½ ,,	,, Fife,	31 ,,
,, Orkney,	41 ,,	,, Perth,	24 ,,
Average,	36¼ ,,	Average,	25½ ,,

According to Professor D. T. Ansted, the average annual rainfall at Bishopswearmouth in Durham, from January

1, 1850, to December 31, 1860, was 16·91 inches, while during the same time the average at Seathwaite in Cumberland was 126·98 inches per annum, or about seven and a half times as much. It is recorded that in 1862 the fall at Seathwaite was 182·58 inches, while during the same year only 19·30 inches fell at Bishops-wearmouth. These figures will give some idea as to both average and extreme rainfall in this country.

What proportion of this mass of water finds its way through the soil? and how much is returned to the air by evaporation from the surface? So much must depend upon configuration of surface, nature of underlying rock, and the absorbent power of various soils, that I am disinclined to adopt any precise figure to represent these proportions. It is also evident that the amount of water which finds its way into drains during long-continued rains in cold weather, will be proportionally greater than during intermittent rains falling in warm weather, when evaporation will claim a much larger share. Bearing these qualifying circumstances in mind, I may mention that Professor Way has assumed 42·4 per cent. of the rainfall to filter through the soil, the remainder being supposed to be got rid of by evaporation and transpiration. This figure is based upon experiments conducted by Mr Dickenson of Abbots Hill, Herts, during eight years, with an ingenious rain gauge specially contrived for the purpose. Professor Ansted considers that the amount of rain evaporated is at least 14 inches, which is 56 or 46 per cent., according to whether the fall is 25 or 30 inches per annum, leaving 44 to 54 per cent. to be got rid of by filtration. Lastly, Mr Lawes and Dr Gilbert found that growing crops of grain or pulse transpired water during their growth in the proportion of from 250 to 300 parts by weight for every part of dry matter they elaborated, and they estimated that a crop of 2½ tons of dry substance must have transpired 750 tons of water per acre through their leaves alone. With respect to the total amount of water evaporated and passed off by plants, Mr Lawes makes the

following remark: "In the admitted defect of satisfactory evidence from which may be deduced the probable average amount of evaporation from the surface of the soil independently of vegetation, we will assume by way of illustration that, taking the average of many soils and seasons, three-fourths of a total rainfall of 25 inches will pass off by the combined action of evaporation from the surface of the soil itself, and of the exhalation due to the growth of a good crop of hay or corn. On this supposition there would still remain more than 6 inches of rain, equivalent to more than 600 tons of water per acre annually passing downwards, and carrying with it more or less fertilising matters."[1]

CHARACTER OF THE SOIL.—Taking the causes of wetness in connection with the character of the land, we have a clue to the water economy of soils. Setting aside minor distinctions, it will be useful for the present to divide soils into two chief classes—(1.) free soils and subsoils, and (2.) clay soils and subsoils. The free soils will be found to consist of friable loams, peats, and vegetable loams, all possessing the property of permeability to water. If a free soil requires draining, it is either because it is wet *from position*—*i.e.*, from effluent or diffluent water pressing upwards into it from lower strata

[1] Lawes and Gilbert, at Rothamsted, Herts, with a gauge $\frac{1}{1000}$ of an acre area, soil rather heavy loam, with clay subsoil (chalk below), built in, in natural state of consolidation, with brick and cement, obtained the following results, from 5th September 1870 to August 1875, after an average rainfall during five years of 28 inches:

	Per cent. of Rainfall.	Per cent. of Rainfall.
With 20 inches depth of soil,	36·8 percolated.	63·2 evaporated.
,, 40 ,, ,,	36·0 ,,	64·0 ,,
,, 60 ,, ,,	28·6 ,,	71·4 ,,

The average result from five series of experiments, conducted at various times, by Dalton, Dickinson, Maurice, Gasperin, and Risler, gave a general mean of 31·3 per cent. of rainfall disposed of by percolation, and 68·7 by evaporation (Dr J. H. Gilbert on Rainfall, Evaporation, and Percolation. William Clowes & Sons, Charing Cross, 1876).

which obtain their supply from higher levels. Or wetness is due to the presence at a greater or less depth of a retentive substratum, which holds up the water by preventing its escape to strata where it would cease to be injurious. In the first case the supply from a distance should be cut off by cross drains, and springs must be tapped on Elkington's principle. In dealing with porous soils wet from surface water, a regular series of drains, similar to those used in draining stiffer soils, will be effective placed at considerably wider intervals (p. 84).

RETENTIVE SOILS.—The argillaceous element in these soils gives them the power of holding and retaining a large quantity of water with considerable tenacity. These are manifestations of that porosity already explained (p. 28); and the same fine state of division of the particles composing them forms a barrier to the free passage of air, as well as of water, through them. That water will pass through clays is evidenced by the fact that they contain it at considerable depths; and again, the fact of water passing through them is proof positive that they are permeable to air. But their need of artificial drainage, and the difficulty experienced in effecting this improvement, satisfactorily shows that they offer considerable resistance to the passage of both air and water. An open drain, cut through retentive and wet clay, exerts but little effect in drawing off the surplus water; and a well sunk in clay does not fill up to the level of supersaturation in the surrounding soil. Even a solitary closed drain does not act freely when placed in such soils, but a series of parallel closed drains, placed at a proper distance apart, appear to assist each other. In a free soil a single drain acts at once, and for a very considerable distance, on either side. In explaining the difference between the action of drains in free and retentive soils, we are repeatedly told, by drainage authorities, that the stiff soils require *aerating*. We must be careful not to underrate the action of the atmosphere in the successful drainage of land, and I have already explained its action (p. 66)

At the same time, no one can believe that water cannot escape from a surcharged soil because air cannot follow. Of the two fluids, air and water, the former is by far the most light and attenuated, and to say that water cannot filter through a soil because air cannot follow, is claiming for clay soils a property which is inconceivable, namely, that they are permeable to water in a higher degree than to air. Once drain off the water, and air will occupy the vacated spaces as a matter of course. To say that air cannot enter a soil which is surcharged with water is one thing, but to say that water cannot percolate through a soil because air cannot follow it, is a very different statement, and one which is untenable.

A retentive soil is composed of exceedingly fine particles. Its interstitial spaces are exceedingly minute and numerous when compared with those of a free soil, and, as a consequence, the surface-attraction is exerted over a very much larger area, and is proportionately stronger. Clay soils are capable of holding a large quantity of water by this surface-attraction (capillarity), and the extreme fineness of its interstitial canals or pores greatly increases the friction, which in all soils more or less impedes the downward passage of water. It seems, therefore, more reasonable to attribute the difficulty of draining a clay soil to *friction* rather than to any difficulty in air following water through it. The amount of effective resistance which a clay soil offers to the passage of water will increase with its thickness, and hence it is no matter for surprise that drains, to be effective upon such soils, must be placed near together. That a solitary drain should fail to drain the soil even in its own immediate neighbourhood, appears to be due to the unbroken continuity of the clay offering an effective opposition to the passage of water. On the other hand, the "reciprocal action" of drains, or the assistance which neighbouring parallel drains seem to render each other, may be explained as resulting from the breaking of the continuity of the mass of clay. When a clay field is regularly trenched from

three to four feet deep, at intervals of fifteen to twenty feet, which is precisely what is done in thorough drainage, the effect of each drain is increased far beyond that which a solitary drain could effect. Water commences to flow and air to enter at a large number of points. Contraction, and the pulverisation and cracking of the clay follows as a natural consequence, and these actions, proceeding as they do from a large number of contiguous centres, quickly permeate the entire mass, and result in what has been somewhat mysteriously termed the reciprocal action of drains. The action of drains is similarly facilitated by deep cultivation. A moment's reflection will show that a single drain in a clay field is placed at a great relative disadvantage compared to one of a series, and hence it is comparatively ineffective.

THE "RESERVOIR," OR SECTION OF SUPERSATURATION. —In every soil requiring drainage, water is present in excess, for the simple reason that it cannot escape. The tendency of water is to sink through the earth, in obedience to the law of gravity; and when it remains stagnant near the surface, we may safely infer that there is a physical barrier which arrests its downward motion. This barrier may consist in an underlying thick bed of retentive clay, which holds up the water almost as completely as though it were held in a basin. Or, less definitely, it may consist in a more or less retentive soil and subsoil, which prevents that free percolation of water essential to the healthy development of vegetation. In either case, the land is apt to become "water-logged," or supersaturated. If supersaturation reaches the surface, a marsh is produced, and if the water overflows, a mere or lake is the result. Wherever a pit dug in the soil fills altogether or partially with water, there is proof positive of this condition of supersaturation, and the section of soil thus supersaturated has been called the "*reservoir.*" The upper limit of the reservoir is called the "*water table,*" and the substratum which holds the water is termed the "*water-bearing stratum.*"

SECTION WET FROM CAPILLARITY.—Immediately above the zone of supersaturation, the soil is wet from capillarity (see p. 29). At the lowest point where this force begins to exert itself, and just above the water-table, the soil is wettest, and the action gradually weakens as the column increases in height, until at thirty-six inches it ceases in even porous soils. The following water determinations were made with a view of illustrating the amount of water lifted by a soil enclosed in a half-inch glass tube, the lower end of which was immersed in water for one hundred and thirty-two days. Five portions of soil, each being higher in the tube than the last, were examined, the first portion being just above the surface of the water outside the tubes. The results were as follows:

1st portion	contained	40·8	per cent. of water.
2d	,,	28·5	,,
3d	,,	22·2	,,
4th	,,	19·3	,,
5th	,,	16·7	,,

From these results, we may conclude that, to effectively drain land, the water-table must be reduced to such a distance below the surface that the roots of plants shall not be perpetually exposed to an unwholesome degree of wetness, and that this will be accomplished if the level of supersaturation is lowered from three to four feet beneath the surface. To secure a thoroughly wholesome condition of soil, the surface ought to be dry or free from this constant supply of capillary water. The evil of a water-table lying too close to the surface is frequently seen in an efflorescence of salts, which exert an injurious effect on vegetation. A soil constantly damp from the action of capillarity will also be rendered cold by evaporation.

ACTION OF DRAINS.—In speaking of the action of drains in drying a soil, we can only speak positively as to tendencies.

That the changes described in books on drainage absolutely take place in every soil, is more than can be believed, because the degree of tenacity, and the presence of disturbing causes of many kinds, must modify the action of drains and the behaviour of water to a very considerable extent. Bearing in mind what has been already advanced, we suppose that a field requiring draining is often in the following state. The water-table has risen well nigh up to the surface, and the entire soil is consequently in a water-logged condition. The accompanying figure will assist to give an idea as to the state of such a soil, and the action of drains. The dotted line A A represents

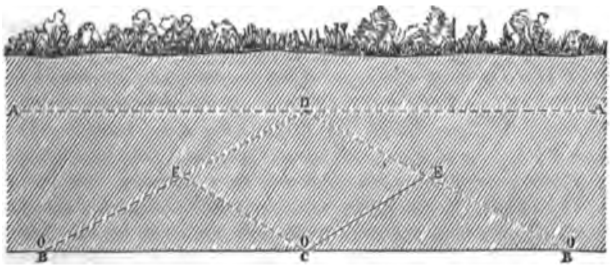

Fig. 5.

the level of supersaturation, or the water-table. Below A A every fissure and interstitial space is full of water, and therefore in a condition unavailable as a feeding-ground for roots of plants.

This surplus water would escape if it could find an outfall, and can only be supposed to keep its present condition because it cannot overcome the resistance of the surrounding and *underlying* soil. If drains were placed at B B, the immediate result would be that the surplus water would flow from them *until the water-table or level of supersaturation was reduced to the level of the bottom of the*

drains, or to B B. It is precisely the same thing which happens when the bung is driven out of a full cask standing on its end—the cask is emptied down to the level of the bottom of the bung-hole. As all soils are more or less retentive, we cannot expect that this effect will be felt at remote distances from any drain. It is true that in very gravelly soils the action of a drain may lower the level of springs a quarter of a mile distant, but in soils of more retentive character the effect steadily and quickly diminishes with the distance, until it ceases to be observable. This limit of the drain's action is represented as being reached at D, where the water-table is shown to remain undisturbed at its old level. The dotted lines D B, D B, indicate the diminishing influence of the drains B B as the distance increases, until the soil at the point D derives no benefit from the drains. The drain C is now introduced midway between B and B, and it will be seen that the effect of the three drains acting together will be the lowering of the water-table, even at its highest points, to E E. Drains should be sufficiently close to lower the water-table to a depth of three feet, more or less, below the surface, midway between any two of them.

It has been remarked that water will not cease to run until the level of supersaturation is lowered to the level of the bottom of the drain. When fresh rain falls it will pass vertically downwards until it reaches the level of supersaturation, which it will immediately tend to raise, and this raising of the water-level will cause the drains once more to run.

To use once more the homely simile of a cask with the bung knocked out: If water is poured into such a cask, it will first raise the water-level until it reaches the bottom of the orifice, and it will only then commence to flow out. So it is with drains in a field, and hence it is allowed that *water enters a drain from below, and not from above.* To place broken stones above drains in order to facilitate the entrance of water into them is therefore manifestly unnecessary.

Another curious fact, often observed, is also readily explained by the above reasoning. When deep and shallow drains occur in the same field—as when a field has been redrained at an increased depth—it is the deep drains which are the first to run. If water entered at the top of drains, it would be impossible to explain the phenomenon, but let any one bore two holes in a barrel, one a foot below the other, and then commence and pour in water. Of course, the lower hole runs first, and so it is in the case of drains. The rain percolates downwards to the water-level, raises it, as in the barrel, and the deeper drains are ready to carry it off, and, in fact, render the shallower drains useless.

So also it has been observed that deep drains discharge more water than shallow ones. This is because shallow drains lie so near the surface that the water-level is speedily reduced to the depth of the drains; but sink those same drains two feet deeper, and they have to keep the water-table constantly to the lower level, which entails more work upon them.

The foregoing sketch of the action of drains is more accurately descriptive of what takes place in "porous" or free soils requiring drainage than in retentive clays. In the last-named soils the water-table or upward limit of supersaturation, is not so distinctly marked, and the entire soil is supersaturated during long periods of the year, from the surface downwards. They are spoken of as "impervious," a term which must only be employed relatively, for all clays are, to some extent, pervious to water. The difficulty is to get the water to move sufficiently quickly through such soils to prevent puddling at the surface. Still it is only in degree that the action of drains in clays differs from that of drains in free soils. No sooner are they laid than they commence to act, and as they remove the surplus water, air enters, and all those beneficial changes take place which have been already described. The ultimate effect is that the section above the drains becomes altered and permeable to water, so that the

movements illustrated in the foregoing figure actually take place freely.

Practice of Drainage.—Want of space prevents me from entering into a lengthy description as to *how* drainage work is to be planned, commenced, and carried out. Such would be, no doubt, the most desirable course to pursue, but the remainder of this little volume, if entirely devoted to it, would be insufficient. I therefore commend those readers who wish for detailed information to the numerous works published on draining, among which I may mention the large collection of papers under the index heading "Drainage," to be found scattered through the Transactions of the Royal Agricultural Society of England, the Bath and West of England, and the Highland and Agricultural Societies' Journals. Wilson's "British Farming" contains a useful article on the subject, as also does Stephens' "Book of the Farm" (3d edition, 1871), and it is scarcely too much to say that every comprehensive treatise on agriculture enters with considerable minuteness into the subject of land drainage.

SIGNS OF WETNESS.—There are seasons when even wet soils appear dry. In winter the presence of water is evident enough, but even here we may be deceived; for dry or drained soils must at times be overcharged with water. Some discrimination is therefore necessary, and we suggest the following signs of wetness as conclusive:

1. The low temperature of wet soils, when in near proximity to drained land, is demonstrated during winter by the snow lying more readily upon them than upon drier and warmer land.

2. Wetness is exhibited in the "glazed" condition of the newly-turned furrow-slice, which contrasts unfavourably with the friable condition of drained land even after a spell of wet weather.

3. Stunted and blighted straw lead to the suspicion that stagnant water is injuriously affecting vegetation.

4. Rushes, sedges, water-grasses, and certain weeds, indicate water both in arable and pasture land.[1]

5. A bleached appearance of grass land far into spring is usually due to the same cause.

MATERIALS USED IN CONSTRUCTING DRAINS.—Nothing perishable or likely to silt up should be employed. No channel is so good as the cylindrical draining pipe, with or without collars. The late Mr Parkes believed 1-inch pipes to be of sufficient bore, and demonstrated their efficacy from practice and by calculation. He found that 1-inch pipes, placed 24 feet apart, would be able, were it required, to carry off $2\frac{1}{2}$ inches of rain in 12 hours, a fall which is quite unknown in this climate. In ordinary practice, pipes of 2-inch bore are preferred for furrow drains, and 3 to 6 inch pipes are employed for the main or carrying drains. Draining tiles should be well and smoothly made, give out a clear musical note when gently struck together, and be free from nodules of lime, always a source of weakness, as they cause the tile to burst.

Stones broken to such a size as to pass through a 3-inch ring, or water-worn pebbles of about the same size, constituted the material used by Smith of Deanstone. In certain localities where stones abound and clay is scarce,

[1] Buckman mentions the following weeds as characteristic of low damp situations: Upright meadow crowfoot (*Ranunculus acris*), Silver-weed (*Potentilla anserina*), Marsh thistle (*Carduus palustris*), Marsh cudweed (*Gnaphalium uliginosum*), Meadow dock (*Rumex pratensis*), Water dock (*Rumex hydrolapathum*), Bog rush (*Juncus bufonius*), Marsh orchis (*Orchis latifolia*), Spotted-leaved orchis (*Orchis maculata*), Hair, Hassock, or Tussac grass (*Aira cæspitosa*), Common reed (*Arundo phragmites*), Sedge or Carnation grass (*Carex*). Among the British grasses the following species are removed by draining, and are an indication of stagnant water: Black bent or Hunger-weed (*Alopecurus agrestis*), Floating foxtail (*A. geniculatus*), Reed canary-grass (*Phalaris arundinacea*), Marsh bent (*Agrostis vulgaris, var. alba*), Purple melic-grass (*Molinia cærulea*), Water whorl-grass (*Catabrosa aquatica*), Hair or Hassock grass (*Aira cæspitosa*), Floating meadow-grass (*Poa fluitans*), Quaking-grass (*Briza media*).

they may still be employed with advantage. Ordinarily their bulk, and the consequent expense of carriage, will determine drainers to discard stones for pipes.

Faggots, thorns, straw, and peat, have all been employed in forming a channel for water. In the reclamation of peat bogs the peat itself forms a very good material for effecting temporary drainage. The first effect of the improvement is to lower the level of the surface, and as this brings the drains near the top, the work has frequently to be done over again, when pipe tiles may be employed. Unless in special cases, such as that just described, the perishable materials above named are not to be recommended.

THE MOLE PLOUGH is a simple contrivance for forcing an egg-shaped or conical piece of iron through the soil. It consists of a strong knife-edged coulter, passing through a strong beam provided with handles. This coulter is furnished at its lower extremity with a conical iron bolt, 15 inches long, and 3 inches in diameter at base. The beam consists of oak or ash, 6½ feet in length, with rectangular cross section, 6 inches by 5 inches at the thicker end, and 4 inches by 4 inches at the bridle. As the beam during the operation lies close to the surface of the ground, the lower side is protected by a plate of iron, in which is a slot for the passage of the coulter, and the fore-end is drawn into an eye to serve as a bridle. The coulter is 7 inches wide by ¾ inch thick behind, and sharpened to cut through the ground in front. It is 2 feet long, and is furnished with wedges, or rack and pinion, to keep it in position and regulate the depth. The share or mole is of solid iron, welded to the head, the length of the sole being 15 inches. The cross section is a triangle with curved sides, 3 inches across base, and 3½ inches perpendicular height, or it may be a cone 3 inches in diameter at base. This implement may be drawn by means of a wire rope and capstan, either by horses or steam power. It makes satisfactory work on clay land pastures, but the burrow or mole track is liable to be obliterated on loamy, or on any

tillage soil. Mr Colvile Browne obtained for me the following notes upon mole-plough draining done on Mr Cox's farm at Long Melford, in Sussex:

I.

1. When done by steam, the total cost was £1, 8s. per acre, including £1, 1s. for hire of apparatus and tiles for main drains.

2. The work was done at the rate of 4 to 5 acres per day.

3. Depth, 32 inches; depth of mains, with tiles, 34 inches.

4. Width between drains, 5½ yards. Bore of mole, 4 inches.

II.

1. With horses, the total cost, including tiles for mains, £1, 6s. per acre.

2. Depth of mole, 16 inches; distance apart, 4 yards; bore of mole, 2½ to 3 inches.

The opinion in the above cases was in favour of steam-power, on account of the superior depth. Mr Cox is also of opinion that with draining 32 inches deep the operation may be advantageously carried out upon arable land as well as pasture when of stiff character.

Fowler's Draining Plough forms the frontispiece to Mr James Donald's useful little book, "Land Drainage" (William S. Orr & Co.). This implement was brought out in 1851, and is interesting as the precursor of the steam plough which that eminent inventor subsequently introduced. The drainage plough consists of a platform supported on rollers or low wheels made of iron. This carries, in a central position, a coulter similar to that of the mole draining plough, capable of being lowered 3½ feet below the platform, and supported by a rack and cog-wheel. At the lower extremity of the coulter is a pointed conical piece of iron, furnished with a hook at the back.

An iron cable with eye is attached behind, and upon the cable pipes are strung necklace-wise. This cable must not be too long, "therefore parts of the drain from 50 to 100 feet from each other require to be previously cut

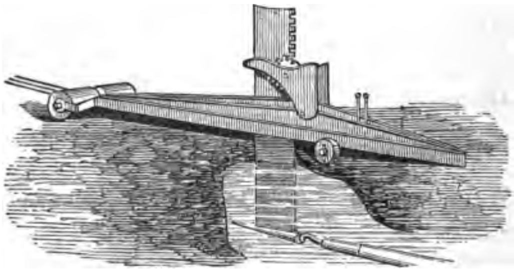

Fig. 6.

with the spade, and the rope with the line of pipes thereon must be of such length as to reach from one of these parts to the next."

The first idea was to draw the machine through the land with horse-power and windlass, and it was also contemplated to employ steam. The drawback which hitherto has been insuperable is the amount of friction, which is liable to break the tiles.

Depth and Distance apart of Drains.—Depth and distance apart ought to bear a relation towards each other, as will be at once seen by reference to fig. 5. In stiff clays drains 3 feet deep can scarcely be relied upon to act effectively beyond 7 to 8 feet on either side, *i.e.*, the distance should not be more than from 14 to 16 feet. In somewhat lighter clays, drains $3\frac{1}{2}$ feet deep, and 21 feet apart, have thoroughly dried the land; and in loamy soils, drains 4 feet deep may succeed at 30 to 36 feet apart, and even more. Mr Girdwood wrote as follows: "I find it necessary to drain from 8 to 10 yards on the Weald and Oxford clays; at from 10 to 12 yards on the

clays of the Red Sandstone, where there is a homogeneous so-called clay subsoil. In such cases the usual depth I employ is 4 feet for the minor drains, and 4 feet 3 inches for the mains." Where retentive and water-holding strata alternate, it is sometimes possible to drain at much wider intervals than those just mentioned. In such cases the land is dried upon Elkington's principle rather than upon Smith's, and the free gravelly substratum, when once tapped, acts as a drain for a great distance. Mr Girdwood proceeds: "When gravel beds occur in the clay or under it, they often permit of wide intervals being used with perfect success. I have drained nearly 200 acres of this kind of subsoil at Sudbury, at 6 feet deep, and at intervals of 44 yards, with the greatest success." The practice of those who have proved themselves successful drainers should receive our best attention. And if we want to test for ourselves the correct distance, trial pits or holes may be dug at intervals across the line of the proposed drains, and the effect of a drain upon the water-level may then be practically witnessed.

Direction of Drains.—Much has been written upon this point, but the unanimous verdict is in favour of draining in the direction of the greatest slope. Like all rules, this one requires to be modified, according to circumstances. It is wise, for example, to deviate from the strict line of greatest slope, if ancient ridges, which, maybe for centuries, have determined the direction of the water, follow a somewhat oblique or circuitous path. By cutting through these ridges, in order to secure an uncompromising line, much drainage has been rendered ineffective.

General Directions.—The following considerations are important, and each is worthy of more expansive treatment than can at present be afforded:

1. The number of outfalls should be reduced to a minimum, as each is a source of weakness.

2. All outfalls should be secured with a perpendicular grating, and be faced up with stone-work.

3. Any springs should be drained off a few inches deeper than it is intended to drain the field generally: by following this rule the two systems of pipes will not interfere.

4. Drains should be laid to intercept any water that may be expected to soak through from higher levels.

5. Main drains should be three inches deeper than furrow drains, so that the latter may deliver their water quickly, and prevent silting.

6. Main drains should be provided with settling tanks, especially when the drainage works are on a large scale. Each settling tank also to be provided with a "man-hole," closed with a flag and ring.

7. The fall ought not to be less than 1 in 220 (Stephens).

8. To avoid the accumulation of sediment, and weakening the main drain, the furrow drains should never enter a central main drain exactly opposite each other, but alternately.

9. The greatest possible pains should be taken to arrange a plan in accordance with the levels, and to secure a good outlet.

Means of Improving the Physical Character of Soils —*Continued.*

Subsoil and Trench Ploughing.—Mr Smith of Deanstone, whose name has already been mentioned in connection with drainage, was the first to call attention to subsoil ploughing as a means of improving land. Furrow drainage and deep ploughing had been practised previous to his time, but we owe their reduction to systematic practice, and their more extended use, to his endeavours. Subsoiling, according to Smith, consisted in breaking the subsoil without bringing it to the surface. He considered it to be a preparatory work, undertaken with the object of facilitating drainage, deepening the staple, and giving the roots of plants access to deeper layers of soil. It was intended, after the lapse of

several years, to complete the work by trench ploughing, but too sudden a mixing of tenacious unweathered matter with the surface soil was regarded as risky. This remark shows the difference between subsoil ploughing and trench ploughing, the first process consisting in breaking or stirring the subsoil, while the latter brings the under soil to the surface.

The implement by which Mr Smith broke up the subsoil in some respects resembled a plough. It consisted of a strong iron beam, furnished with stilts or handles, and the usual attachment for horses. A plough body, strongly fixed to the beam, further supported the tine or tooth by which the work was effected. There was no mould-board or turn-furrow, and the entire work consisted in splitting the subsoil to a depth of about 12 inches below the bottom of the furrow. A common plough, drawn by four horses, first turned out a furrow 10 to 12 inches deep, and the subsoil plough followed with

Fig. 7.—Improved subsoil plough, with wrought-iron body, adapted to stir the subsoil thoroughly to a depth of from 12 to 18 inches on any land. It is intended to follow an ordinary plough, and is so strong that there is no fear of breakage. Weight, 2 cwts. 3 qrs.

four, six, or even eight horses, breaking the bottom of the furrow to an extra depth of 14 inches. Fig. 7 represents a more modern form of subsoil plough, as manufactured by Messrs Ransome, Sims, & Head, of Ipswich.

Subsoiling has been effectively done to the depth of 3 feet by steam-power, by a subsoiling knife or coulter,

attached to the frame of the plough, and drawn simultaneously through the ground with the plough.

An adaptation of subsoiler to a double plough body, manufactured by Messrs Ransome, will assist to give a clear idea as to the nature of this operation:

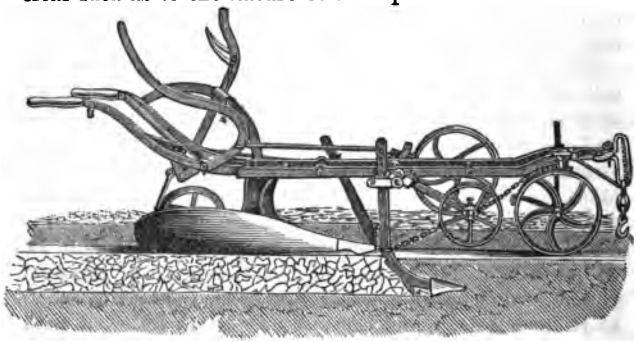

Fig. 8.—Double plough, with patent subsoiler instead of the front body. The subsoiler works at the bottom of the furrow, and being in advance and to the right-hand side of the hind or breasted plough, as soon as the bottom is pulverised, the hind plough turns a furrow completely over the subsoiled portion, which is therefore never trodden by the horses. It will be seen that the horses always walk on the solid bottom.

This is a most efficient way of subsoiling when it is not required to do any extreme work which might necessitate the employment of a separate implement, and will work well to a depth of 10 or 12 inches.

It is generally allowed that subsoiling is especially beneficial where the soil is underlaid by a hard, gravelly, or calcareous substratum, sometimes called a "pan." In such cases injury is done both by stagnant water puddling the surface, and the obstruction offered to the downward passage of roots. The subsoil plough at once obviates these disadvantages, and by allowing free access to water, air, and vegetation, to a lower stratum of soil, assists to deepen the staple.

On the stiffest classes of clay, subsoiling is found to be only temporary in its effects. These soils are apt to return to their original condition, so that a year afterwards scarcely a trace of the work performed by the subsoiler remains.

Trench ploughing is effected similarly to the operation just described; but the subsoil is brought up and mixed with the surface soil. The late Marquis of Tweeddale relied much upon trenching as a means of improving land after it had been thoroughly drained. The late marquis took a great personal interest in the improvement of his estates in Haddingtonshire, and invented a subsoil trench plough adapted for his own requirements. In this implement the ordinary tooth or tine was supplemented by a tail-board or inclined plane, by which the subsoil was brought up to the surface. The inclined plane was attached immediately behind the disturbing tooth, and the loosened earth was gradually forced upwards as the subsoiler was drawn through the ground.

Trench ploughing is a more critical operation than subsoiling. It may be done with unquestionable benefit on deep alluvial lands, where the quality of the subsoil is equal, and perhaps even superior to that of the surface soil. To bring up raw clay and mix it with the cultivated soil is certainly questionable policy; and although the judicious mixing of soil and subsoil is no doubt often attended with good results, it should be undertaken with caution, and upon a small scale at first. Cases might be cited in which positive injury has been done by deep ploughing through the bringing up of ferrous salts to the surface.

The plan adopted by many good farmers of gradually deepening the staple of their soils by ploughing their fallows a little deeper than usual in the autumn is to be recommended. Thus lands intended for root crops will be ploughed deeply the previous autumn, and the winter's frost will effect the pulverisation of the fresh earth.

CLAY-BURNING.—The plasticity of moist clay has been mentioned as a property of great value, since it enables the potter to fashion clay into any form he pleases. The action of heat in completing the manufacture of pottery is well known. The plastic mass becomes rigid and brittle, and when exposed to the action of water it is no

longer capable of becoming diffused through it. The texture is completely changed, so that, if beaten up into fragments, it forms a powdery mass, possessing no cohesive power. It is this fact which is taken advantage of as a means of improving clay lands. In burning clay for agricultural purposes, a less severe heat is employed than in the kiln. A low red heat, which will leave the clay in a crumbly condition, is the best, and a clinking brick-like ash is avoided.

Upwards of thirty years ago the late Mr Phillip Pusey collected a valuable correspondence upon this subject, which appeared in the *Journal of the Royal Agricultural Society*. One of the most valuable of these letters is from Mr Francis Pym, vol. iii., p. 323, where he describes his mode of procedure as follows: "The work is begun in May, and continued through the summer, in heaps containing from 50 to 100 cubic yards each." The great art is to let the clay burn slowly, and this depends very much upon the formation of the heap. When properly burnt, the ashes turn out black, *in which state they are considered much better than when they are red and clinking like bricks.* Turf is used for building the walls of the clamp or heap, and faggots, roots, and brushwood, for raising a sufficient heat; and "if sufficient turf can be raised, with the assistance of a few roots or faggots, a great deal of clay, containing very little vegetable matter, can be reduced to ashes. The fire requires watching day and night, and the clay always burns best when it has been dug a week or two." Another correspondent says: "The heat should always be slow and steady—never, if possible, burning the clay red, but black."

Mr Mechi's plan of proceeding is as follows: The clay is broken up in *very dry* weather by a strong plough, which is very severe work. The large pieces are used for building the walls of the clamp, and the smaller fragments for filling up the interstices and keeping in the heat. The fire is lighted with roots and waste wood,

and the clay is piled upon and around it, taking care that the walls are kept as upright as possible. The clay is carried and laid on first by hand, but as the heap increases in size it is wheeled in barrows. Judgment is required to supply the clay at such a rate as to keep the fire from bursting through the walls, and yet not so fast as to exclude air and extinguish it. Mr Mechi puts about 200 cubic yards together in one heap. Mr Randell of Chadbury has also contributed an excellent description of his method of burning clay with coal to the pages of the same journal.

With regard to results, Mr Pym stated that he had succeeded in raising the average produce of wheat nearly 10 bushels per acre, and other crops in proportion, on two farms which he had occupied, the one on the Gault clay in Cambridgeshire, and the other at Baldock.

The quantity used was 40 to 50 yards per acre, applied at a dry time, as soon as convenient after harvest. He considered the effect lasted seven or eight years. Mr Pusey also gave an instance of the improvement of 500 acres of land on the Oxford clay. This farm originally cost £14 per acre. After draining and clay-burning the crops in one year were worth £17 per acre! In this case 80 loads per acre were used.

The causes of the efficacy of burnt clay have been pointed out by Dr Voelcker: (1.) The altered mechanical texture; (2.) The amount of matter soluble in acids increased from 6 to 9 and 10 per cent., this increase being principally in oxides of iron, potash, and soda. On the other hand, phosphorus pentoxide is rendered slightly less soluble, and the nitrogen is dissipated. Thus the effect upon the mechanical condition of the land must be considered the chief reason of the efficacy of clay-burning.

Paring and Burning.—This is a tillage operation of much less importance than that last described. It is introduced here in order that the differences between it and the last process may be clearly stated. Clay-burning

involves the burning of a considerable depth of earth—it may be more than a foot. Paring and burning means the burning of only the top inch, or at most two inches, of the soil. The first is undertaken as a durable improvement, calculated to alter the texture of the land; the second is done with the object of destroying weeds, and the eggs and larvæ of destructive insects. The first is a landlord's or leaseholder's operation; the second is undertaken by yearly tenants.

Paring and burning is done by means of a paring plough, or a plough fitted with a broad or paring share, as in fig. 9, and is usually practised upon old sainfoin, or old seeds, when they have become very foul, and infested with insects. The work is best done by "raftering" the surface, an operation which may be rendered intelligible by the following figure, representing raftering in section.

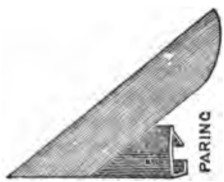

Fig. 9.

The deeper depressions show the path of the paring plough, and the thin furrows which

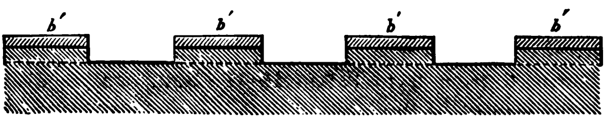

Fig. 10.

have been thrown out are shown at *b′ b′*. The remainder of the ground may be "breast-ploughed" with a sharp-edged shovel, or with the implement first used. Thus the entire surface is pared during the winter, and in the spring burning completes the work. A Cotswold farmer thus describes the process:

Stifle (or close) burning obtains much in this neigh-

bourhood, chiefly for the production of turnips. Generally after a corn crop, or after a new or old clover lea, the land is ploughed thin, and after sufficient harrowing and rolling, to reduce the clods to a moderate size, the light weedy part is raked together into small heaps at proper distances; the loose surface clod and the fine earth is then pushed with the back of the rake in a ring around the bottom of each heap, which is then lighted with a wisp of straw before placed in the heap. After a little time all the cloddy ring of earth is spread evenly over the fire with an iron shovel, and made firm, which stifles the fire and diffuses the heat through the whole mass. The ashes are subsequently evenly spread and ploughed in.

Paring and burning has been objected to as wasting organic matter containing nitrogen, and it has been suggested that the plan of making composts is preferable. The process is not generally practised, but prevails upon the Cotswold Hills and on other thin soils. It may, however, be urged in its favour that it quickly gets rid of much "trumpery" and rubbish, and there is no doubt the ashes will help the land to grow a good crop of turnips. It is further argued, that if the burning is followed with a good crop of roots fed on the land with sheep, the organic matter and nitrogen wasted in burning will be fully restored to the soil.

MIXING SOILS.—Another means of improvement open to agriculturists is that of mixing soils of different natures together. (See *Chalking* and *Marling*, p. 132).

Mr Dixon of Holton, Lincolnshire, converted a sandy tract of 500 acres, which was thrown into his hands by a tenant refusing to occupy it at a rent of £50, into a useful piece of light land worth 16s. per acre. The way in which this improvement was effected was by underdraining with tiles, and subsequently applying 60 yards of clay or marl to the surface. The land was then worked for roots, followed with barley sown down with seeds, when 30 additional yards were applied. The

effect of adding clay to peat and sandy soils is well known and much practised. Sand, however, has but little effect when applied to clay, unless used in overwhelming quantities.

Occasionally subsoils may be ploughed or dug up with advantage to alter, mitigate, or enrich a soil, as in the application of marl. Good soil, which in the course of years has slipped down hill-sides into the hollows, may, when the opportunity presents itself, be carted and once more spread upon thin places.

The advantage of mixing soils of various characters together is illustrated on the grandest scale in nature when two or more geological formations contribute to the mass of a soil. Upper green sand, when mixed with the marls of the superimposed Lower Chalk, gives a soil of great natural fertility; the richness of the vale of Aylesbury is due to the soil being contributed from many adjacent formations. A remarkable instance of the improvement of the somewhat stiff soils of the Cornstones of the Old Red Sandstone, by a mixture of silicious matter, is found in the valley of the Dor, of which Thurnaston is about the centre. Here much sandy matter has been washed from the hills, and with the Cornstone has formed a soil of uncommon fertility, known locally as the "Golden Valley." Also in West Yorkshire, where the limestone hills have been washed by streams, a soil of great depth and high fertility has accumulated, as in the valleys of the Ure and the Swale.

WARPING is restricted principally to South-East Yorkshire and North Lincolnshire, where the rivers Humber, Ouse, Trent, and Donn flow sluggishly towards the sea, charged with large quantities of suspended matter (mud). The deposition of this matter has resulted in the formation of considerable tracts of alluvial land both on the north and south banks of the Humber, and the new land is still encroaching on the sea, especially at Spurn Point.

Warping consists in the regulation of the deposit, by conveying the water on to the low-lying land in the neigh-

bourhood of these rivers, and allowing it to deposit its burden of mud. By this operation a completely new soil is formed of from 1 to 3 feet thick. One of the most considerable enterprises in this direction was undertaken by Ralph Creyke, Esq., who in 1821 obtained an Act of Parliament to enable him to construct works for the warping of Thorne Waste, three miles distant from the Ouse. The junction was effected by a canal three miles long, furnished with sluices to regulate the flow of water.

Before land can be warped it requires to be embanked, so as to confine the water upon the required space. The main drain being cut up to the newly-embanked "compartment," the Spring tides are suffered to flow in. By limiting the operation to this season, the ditches and canals are scoured by the return of the water after it has deposited its mud—a most important consideration, as the warp is apt to fill up the channels which conduct it to the compartment. The flow of the water conducted by the main drain into the embanked allotment is regulated by smaller canals called "inlets," and conducted to different parts of the compartment. Wherever the current expands upon leaving a canal, there the greatest quantity of warp is deposited. As soon then as the portion next the mouth of the inlets has received a sufficient quantity of deposit, the inlets are extended by what are termed "call banks," which, though small, are sufficient to carry the flood onwards to parts not acted upon by the currents before. One of the chief points aimed at is to get the warp deposited evenly. The depth of the deposit in a single season varies from 1 to 3 feet, and this may be caused by about twelve tides. The compartments may be of large size, 160 acres being spoken of by Mr Creyke as a small one.

TILLAGE OPERATIONS.

Although tillage operations are of constant recurrence, and can hardly be classed with the durable or permanent

improvements already noticed, it must be allowed that they greatly modify the physical character of the soil. They aid the natural forces of heat, moisture, and vegetation, which are ever at work disintegrating the undissolved mineral matter of the soil. No implement is so effective in pulverising the ground as FROST; neither can any tillage operation be effective unless timed with regard to the conditions of moisture in the ground. Considerable attention has already been given to the nature of those changes, by which insoluble mineral matter is gradually reduced into a soluble condition available for plant food. These changes are accelerated by tillage much in the same way as pounding in a mortar facilitates the solution of an intractable substance. Every student who has worked in a laboratory knows that some substances require to be ground to an impalpable powder in an agate mortar before they can be persuaded to dissolve. The process of stirring, by which fresh particles of the solvent are brought into contact with the substance to be dissolved, may also be used to illustrate the advantages of tillage. Tillage acts in much the same manner. It acts by dividing the soil and exposing fresh surfaces to the air, and every other influence which acts upon a soil. Tull thoroughly appreciated the value of tillage, and attributed the beneficial action of dung to its fermenting and dividing power upon the soil (see p. 101)—"Plough it, harrow it as often as you please; . . . grind dry earth to powder; the longer it is exposed or treated by these or any other method possible, instead of losing, it will gain the more fertility." [1] Liebig insisted equally upon the perfect division of the soil by tillage implements as a means of hastening the processes by which plant-ash ingredients are increased from the insoluble store composing the bulk of all soils.

Tillage also acts beneficially by facilitating the passage of water downwards to the drains, and upwards to the roots, by capillary action. It is also the means used by

[1] Jethro Tull's "Horse-hoeing Husbandry," Cobbett's ed., 1822.

farmers for eradicating weeds. We are therefore able to assign three important directions, in which good tilth assists the growth of crops.

The ordinary means used for securing a good tilth are *Ploughing*, "*Cultivating*" or *Grubbing*, *Harrowing*, and *Rolling*.

Ploughing, as understood by English farmers, involves the inversion of the soil by means of a turn-furrow or mould-board. It is this inversion of the furrow at certain seasons of the year which constitutes the special advantage of ploughing, and also renders the operation critical, and even undesirable at other seasons.

The plough is well suited for deep autumn work, in anticipation of root crops; and although steam cultivators and digging-breasts have in some degree superseded ploughing at this season, deep ploughing with three or four horses is still considered excellent practice. One deep ploughing is all that clean land requires. When land is foul, a second, and even third, ploughing may be necessary before the seed time for the root crop arrives. It is impossible to lay down a rule with reference to the number of tillage operations required in order to bring about a proper state of tilth. The following principles should, however, be always kept in view:

1. To obtain a *fine*, *moist*, *deep*, and *clean* seed bed.

2. To induce the three first of these conditions by a deep winter furrow, which will be acted upon by the frosts of winter.

3. Although a second winter furrow or an early spring ploughing is often advisable, yet *late* spring ploughing should be avoided. In the case of stiff lands, it buries the fine soil produced by changes of temperature, and brings up hard clods to the surface, not likely to be ameliorated at this season of the year. In the case of light lands, it promotes evaporation and causes the loss of moisture.

4. Provided land is clean, spring cultivation should be sparingly used; for if autumn and winter tillage have

caused the soil to become fine and moist to a sufficient depth, extra cultivation only adds to the expenses of the farm.

5. The grubber or cultivator will be found better adapted for spring work than the plough.

The last remark leads us to the consideration of the class of implements called *grubbers*. They have come into favour within the last thirty to forty years, although they were used to a limited extent before that time. The grubber, in whatever form it comes before us, consists of a frame carrying tines or teeth, which descend obliquely from the frame. These teeth are invariably curved forwards, and in this respect as well as in their length differ from harrow teeth. These implements, when drawn through the ground, stir it to a depth of some 5, 6, or more inches; and as they may be made to carry broad feet or shares, they cut weeds and stir the ground simultaneously. As they do not invert the soil, they do not promote evaporation, or yet bury the fine mould and bring up intractable clods as the plough does; and for these reasons grubbers are better adapted for spring work.

On the other hand, grubbers have been accused of forming a shallow tilth, and of encouraging the growth of thistles, docks, and colt's-foot. The plough is certainly a very thorough implement, and its share will cut every weed that comes in its path. The cultivator as usually constructed is apt to pass tap-rooted weeds; but there appears to be no reason why a strong cultivator, armed with properly-adjusted broad feet, should not act quite as effectively as the plough. This objection has not been urged against cultivators drawn by steam. For couch (*Triticum repens*), the cultivator is most efficacious, as it draws out the long underground stems, unbroken, while the plough cuts them, and therefore disseminates them through the land.

Harrows are employed for a variety of purposes. Heavy drag-harrows are employed to turn over clods

and expose fresh surfaces to the sun. Seed harrows first level and render fine the surface, and then follow the drill in order to cover up the seed. Grass-seed harrows are of still lighter structure, and are intended to cover clover and grass seeds, which should not be buried to too great a depth. Chain harrows are employed to brush in grass seeds, render the surface of land fine, and on grass land to brush in applications of farmyard manure. They take the place of the old-fashioned brush-harrow.

Rollers are of several sorts. The light wooden roll smooths the surface for fine seeds, and at the same time checks evaporation by diminishing the number of points from which it can take place. Plain iron rollers are chiefly useful for grass land. The Crosskill roller or clod-crusher was originally intended to forcibly grind clods to powder, and thus reduce intractable clay soils to a fine tilth. Such is, however, not the correct principle of action. It is by timing operations with the seasons, and not by main force, that land is brought into the requisite degree of fineness. Were it possible to reduce clods with a heavy roller, the particles would be dry and unpromising for vegetation. Or should the implement be used upon a comparatively moist surface, the result will be a fine top, but a loss of depth by the pressure upon the stratum immediately below.

Crosskill and Cambridge rollers have their proper place as tillage implements, but rather as compressers of light soils than pulverisers of heavy ones. It is not to be denied that even as pulverisers they may be used, if used with judgment; but their chief value has already been indicated—to consolidate light land previous to wheat sowing, to press the earth about the roots of winter-sown crops in the spring, and to roll wheat or other crops heavily when attacked by the wire-worm. These are more reasonable uses for a heavy roller than attempting to coerce clods upon a heavy-land field.

PART II.

MANURES.

CHEMICAL FUNCTIONS OF MANURES.—At p. 49 a list of substances, found in all fertile soils, and also in the ashes of all cultivated plants, was given. Attention has also been called to the importance of nitrogen as a plant food. The removal of crops from a field, or even of bones, flesh, milk, and wool, causes a drain upon these elements of fertility, and, if persisted in, produces at length an impoverished condition of soil, that renders the labour of cultivation unremunerative. Fields thus robbed of their available plant food are spoken of as exhausted, and before they can be worked to a profit, their fertility must be restored by MANURING.

In other cases the soil is naturally poor, or it may be deficient in some particular constituent capable of being artificially introduced. Lastly, it may be the object of the cultivator to raise some crop requiring an extraordinary amount of some element procurable as a manure in the market.

Whether from exhaustion, natural poverty, or the exigencies of a particular crop, manures are very generally required, and almost universally employed. They must be regarded as *plant food, introduced and incorporated with the soil, in order to supplement the store of naturally occurring ingredients.*

Although manure and plant food are in many cases convertible terms, many substances applied to land exert other effects besides that of increasing the stock of plant

food. Lime, for example, although an integral part of all plants, and therefore an important item in all soils, acts upon both the organic and inorganic constituents of soils. The former it assists to decompose and render harmless or directly useful, and the latter it acts upon by decomposing their silicates.

Nitrate of soda and sulphate of ammonia are no doubt themselves sources of nitrogen to growing plants; but these substances, when dissolved by water, greatly increase its solvent action upon the mineral matter of the soil. As a solvent, common salt may also be included with the above. "Thus," the late Baron Liebig wrote, "chloride of sodium and the nitrates act in two distinct ways: one direct, by serving as food for the plant; one indirect, by rendering the phosphates available for the purposes of nutrition" ("Laws of Husbandry," p. 79). We may therefore conclude that several manurial substances act upon the silicates containing alkalies and the phosphates native to the soil, and therefore upon the most important ash-ingredients of plants.

Physical Action of Manures.—A third and highly important effect of manures is, that they alter and improve the physical character of the soil. This property is possessed in a high degree by lime, which is therefore seen to exert three distinct influences on the soil. Stiff land works distinctly easier after liming, and sandy soils are rendered to some extent more compact. The beneficial action of marl is greatly due to its giving a degree of consistency to sandy soils. The high estimation in which farmyard dung is held by farmers is greatly due to its mechanical effect upon the soil; and so important did this feature of the value of dung appear to Jethro Tull, that he ascribed its entire value to its mechanical action in dividing or pulverising the soil. "Its use is not to nourish, but to dissolve, *i.e.*, divide, the terrestrial matter which affords nutriment to the mouths of vegetable roots" (Tull). The importance of dung as a solvent and preparer of earthy matter native to the soil,

is fully recognised in Liebig's works; and it must be allowed that the decomposition of straw in a stiff clay opens up minute channels, favouring the percolation of water and the admittance of air.

General and Special Manures.—The terms "general" and "special" are applied to manures according to the degree in which they are capable of thoroughly keeping up the fertility of land. A field from which the constituents of wheat, wool, bone, and milk, are being perpetually drained, can only be kept up in condition by the return of these constituents. Any substance which can repair the entire loss is entitled to be called a general manure, just as milk, which is well known to repair all waste, and at the same time supply all the necessary materials for building up the animal body, is spoken of as a "general food."

The best type of a general manure is rich farmyard dung. Such dung consists, first, of the excrements and urine of animals fed liberally upon roots, hay, and probably corn and cake. These voidings are rich in all the ash-constituents of plants as well as nitrogen. In addition, there is straw in abundance, so that well mixed and made farmyard manure contains all the elements of both corn and straw, and is therefore well calculated to give back to a field what it has lost in the ordinary course of husbandry. Chemical study further confirms this view, and shows that this popular manure stands forward prominently as a true "general manure."

Special manures contain one, two, or more valuable constituents of plant food, but are not sufficiently complex in composition to keep up the fertility of soils. They must, however, be regarded as highly useful under the following circumstances: (1.) When a soil is deficient in some particular element of fertility, as lime, magnesia, or phosphates; (2.) When a crop has some particular requirement; (3.) When soils are in high condition, and it is undesirable to stock them further with artificial fertility, special manures may be employed to bring out, and pos-

sibly to reduce their surplus wealth, by stimulating the growth of heavy crops.

USES AND ABUSES OF SPECIAL MANURES.—The first two cases in which special manures have just been recommended need not detain us further. But the third case, in which special manures are employed as a "whip," requires a little explanation.

If nitrate of soda is applied to a wheat crop, the usual effect is a considerable increase in the yield both of straw and grain. Since nitrate of soda contains only one important constituent of plant food—nitrogen; and since the increased yield of wheat, owing to the application, removes from the soil a certain proportion of earthy matter as well as nitrogen, it is evident that the soil has been drawn upon to a greater extent than it would have been without the application. In this case, then, the nitrate of soda has actually reduced the stock of wheat ingredients in the soil. A soil thus treated year after year would be sooner exhausted than one cultivated without the aid of a manure of this class. This being the case, it is of importance to landowners to know how far the application of nitrate of soda is to be recommended.

If nitrate of soda were employed alone, and year after year, no doubt the land would suffer, although many years might elapse before the evil effects became apparent. It certainly would not improve. If, as is usually the case, the farmer who employs the nitrate is in the habit of applying other fertilisers, such as "town manure," superphosphates, and lime, and also yearly consumes cake and corn upon the farm, the use of nitrate of soda becomes reasonable and right. The management is liberal and of an improving character, and the nitrate of soda only brings out the artificial fertility which comes of good farming, and does not prey upon the natural fertility of the soil. The same remark would apply to the use of other special manures, such as lime. Repeated liming, according to the old proverb, "while it enriches the father, impoverishes the son." But lime applied in

conjunction with liberal management cannot be objected to on the score of exhausting the land.

POSSIBLE LIMIT TO THE PROFITABLE USE OF ANY MANURE.—As long as a soil is deficient in a particular constituent, we may expect to see benefit from its application. If the land becomes sufficiently stocked with this constituent, we may find a change of fertilisers desirable. If a soil contains a sufficient proportion of phosphoric acid for the requirements of a wheat crop, and at the same time an excess of potash, we cannot expect a dressing of potash to be attended with any effect. A soil deficient in lime may be greatly benefited by an application of lime. But a second or third application of the same substance might produce but little effect, simply because lime had ceased to be a deficient element. Up to the present time, potash (owing to its existing in considerable quantities in farmyard manure) has not been lacking in most of our soils. If, however, from the cultivation of the potato, the growth of wool, or the sale of straw, the amount of potash became reduced below the point required, then a demand for potash salts would immediately spring up.

LIEBIG'S "LAW OF MINIMUM" springs naturally from the above considerations. "Every field contains a *maximum* of one or several, and a *minimum* of one or several nutritive substances. It is by the *minimum* that the crops are governed, be it lime, potash, nitrogen, phosphoric acid, magnesia, or any other mineral constituent." It is by increasing the proportion of deficient constituents, and not by adding to the quantity of those in excess, that the effects of manures are rendered apparent. Hence the discordant verdicts with reference to the action of any particular fertiliser. Potash to a field deficient in potash; lime to a field deficient in lime. But not lime to a field deficient in potash, is the proper course to pursue.

APPLICATION OF LAW OF MINIMUM TO FARMYARD DUNG.—As a "general manure" it has already been seen to contain all the requisite constituents for the

growth of plants. The exhaustion of a field is due to the removal of the very constituents which yard manure is ready to give back, and the directions in which these benefits are realisable are as various as its constituents are numerous. I cannot do better than quote from Liebig himself upon this point: "Upon a field deficient in potash, farmyard manure acts by the potash contained in it; upon a soil poor in magnesia or lime, by its magnesia or lime; upon one poor in silicic acid, by the straw in it; upon land poor in chlorine or iron, by chloride of sodium, chloride of potassium, or iron contained therein."

Farmyard manure not only is unrivalled in composition, but its value is enhanced by its action on the soil during its decay. No other manure exerts such a powerful chemical and mechanical effect, and no other can be applied to all sorts of land with such positive certainty of effect. It is also found to be peculiarly durable in its effects, and these merits are quite sufficient to account for the high estimation in which dung is held by the farmer.

Farmyard Manure.

The concluding remarks of the last section sufficiently show the importance of farmyard manure. It is, however, well known to all practical men, that under the term dung, or farmyard manure, much comparatively worthless material may be included. The quality of dung depends upon a considerable number of circumstances, which may be thus enumerated:

1. Upon the species of animal producing it.
2. Upon the age and condition of the animal.
3. Upon the food of the animal.
4. Upon the accommodation of the animal.
5. Upon the amount and quality of litter supplied.
6. Upon the management during its accumulation.
7. Upon its after-treatment.

The domestic animals which furnish the farmer with the most valuable portion of his manure-heap are cattle,

horses, and pigs, and in rarer cases sheep. The dung of CATTLE forms the staple. It is generally of a somewhat thin and watery consistency, and is consequently not likely to heat rapidly, even when massed together. The cool character of cow dung is illustrated by the fact that grooms employ it to stuff their horses' feet at night for the purpose of keeping them cool and moist. HORSE dung is voided in a drier state, and is therefore much hotter in its character. Horse dung is chosen by gardeners to make their hot-beds, and to place under forcing frames. If heaped together in large quantities, it is liable to a form of dry-rot or "fire-fang," which is readily detected by a white dust that soon encrusts the straws, and causes dryness and lightness throughout the mass.

PIG dung is cool in its nature, like that of cattle.

Owing to these differences of nature, it is desirable that dung should be well mixed together, and this has an important bearing upon the designing of farm-buildings.

AGE AND CONDITION OF THE ANIMAL.—*Adult animals* allow a larger proportion of nutritive food-constituents to pass through the alimentary canal than young and growing animals. Phosphates are reserved for the formation of bone, nitrogen and salts for the development of muscle and blood, in the case of young animals; whereas, in mature bodies, the processes of decay and elimination keep pace with those of nutrition. *Lean* animals absorb more nutritive matter from the food supplied than those which are fat or forward in condition. Hence the dung of fatting bullocks becomes richer as they ripen. *Cows in calf* and *in milk* are in the same condition, with reference to the food consumed, as growing cattle, for they have not only to feed a *fœtus*, but in most cases to yield a supply of milk.

FOOD OF THE ANIMAL.—Beasts fed upon straw, or straw and turnips, furnish an inferior manure altogether to cattle receiving corn and cake. This difference is recognised by practical farmers everywhere, and in Lincolnshire half the market value of linseed-cake consumed during the

last year of his tenancy is allowed to an outgoer, and cheerfully paid by an incoming tenant.

The difference in value between the excrementitious residue of a ton of straw, a ton of turnips, of barley meal, of linseed-cake, and a variety of other substances employed as cattle foods, has been estimated by Mr Lawes, and reduced to a money standard. It is not necessary that these figures should be accepted as precisely fixing the commercial value of the manurial residue left by the consumption of the various foods mentioned. The figures are based upon chemical data, but in each case will require to be discounted rather heavily to compensate for the inevitable, as well as preventible, waste that always occurs.

ESTIMATED VALUE OF THE MANURE OBTAINED BY THE CONSUMPTION OF ONE TON OF DIFFERENT ARTICLES OF FOOD, EACH SUPPOSED TO BE GOOD QUALITY OF ITS KIND.

1.	Cotton seed-cake, decorticated, .	£6	10	0
2.	Rape-cake, ...	4	18	6
3.	Linseed-cake, ...	4	12	6
4.	Cotton seed-cake, not decorticated, .	3	18	6
5.	Beans, ...	3	14	0
6.	Linseed, ...	3	13	0
7.	Peas, ...	3	2	6
8.	Indian meal, ...	1	11	0
9.	Locust-beans, ...	1	2	6
10.	Malt-dust, ...	4	5	6
11.	Bran and pollards, ...	2	18	0
12.	Oats, ...	1	15	0
13.	Wheat, ...	1	13	0
14.	Malt, ...	1	11	6
15.	Barley, ...	1	10	0
16.	Clover-hay, ...	2	5	6
17.	Meadow-hay, ...	1	10	6
18.	Bean-straw, ...	1	0	6
19.	Pea-straw, ...	0	18	9
20.	Oat-straw, ...	0	13	6
21.	Wheat-straw, ...	0	12	6
22.	Barley-straw, ...	0	10	9
23.	Potatoes, ...	0	7	0
24.	Mangel-wurzel, ...	0	5	3
25.	Swedish turnips, ...	0	4	3
26.	Common turnips and carrots, . .	0	4	0

Accommodation of Animal.—In ordinary practice live stock are housed either in (1.) stalls or byres, (2.) yards more or less covered, or (3.) boxes. Apart from those considerations referring to the comfort and health of the animals, the effect of each of these modes of housing upon the quality of the manure is very considerable.

Stalls or byres involve tying up the animals, and as this prevents free movement, the dung is all dropped in one place, and is very imperfectly mixed with the straw. These stalls are daily cleaned, and the dung and litter should be removed and spread over an open or covered yard, to be more completely trodden down or made. Where straw is scarce or commands a high price, the system of tying up in byres is in favour, as it is economical of litter.

Boxes are highly favourable to the production of first-class manure. In the first place, they are invariably covered with a roof, which protects the dung from rain. All the moisture contained in box-made dung is therefore derived from the animal, and in consequence a less amount of straw is required than in the case of open yards. Boxes are generally devoted to fatting cattle living upon a highly nutritious diet, so that, apart from the protection they afford from rain, this constitutes another substantial reason why box-manure has obtained a high reputation.

Yards.—Of late years covered yards have been advocated, and where these have been erected, the conditions are identical with those of boxes. More commonly the yard is furnished with a shed, but is for the most part open to the sky. As cattle are only housed in winter, the season in which the greatest amount of rain falls, open yards receive a large quantity of surplus water; and, especially when the sheds are not spouted or troughed, the manure becomes much wasted, and the quantity of litter required to keep the cattle comfortable is greatly increased. These conditions are not at all favourable to the accumulation of really good dung, and the system cannot be continued profitably when large

sums are being expended upon feeding stuffs. At the same time, it is claimed as an advantage by those who advocate fold-yards and sheds, that they enable the farmer to crush down his straw and make it into manure. In certain rural districts, perhaps, the "crushing down" of straw may be an advantage, but the idea savours of the past.

AMOUNT AND QUALITY OF LITTER SUPPLIED.—This condition has already occupied us to some extent. To furnish litter *ad libitum*, so that the yards and boxes are always knee-deep in clean straw, is conducive to the comfort of the animals, but certainly impairs the quality of the manure. On the other hand, fold-yards kept in a spongy, miry condition favour the escape of valuable materials by surface drainage and evaporation. Many good farmers endeavour to take a middle course, by allowing their courts to become miry, or the black liquid to be seen once or twice a week, before fresh straw is added. Another point of importance is the thorough mixing of the various sorts of dung. Buildings, as already mentioned, should be contrived with a special view to this end. Stables and stalls should open into, or be placed opposite, the gates of fold-yards, that the half-made manure may be spread abroad and thoroughly mixed. On no account should horse dung be allowed to accumulate in masses by itself. Pig-sties should be so placed that the swine may have access to the yards, where they will not only act as scavengers, but rout up and mix the manure. Pains should be taken to litter the yards evenly, and when necessary, to level the surface. Lastly, the more the yards are protected from rain and snow, the better will be the quality of the manure produced.

AFTER-TREATMENT.—Passing over the management of dung during its accumulation, as already sufficiently indicated, we come to the after-treatment, which must be allowed to exert an important influence upon its efficacy. The tendency of late years has been in the direction of simplifying the processes by which dung was formerly prepared for application. In the opinion of many leading

agriculturists, the best plan is to cart direct from the fold or box, spread the dung on the land, and plough it in. The limits within which this method may be recommended are (1.) during the autumn or early winter, when "long" or "green" dung may be safely ploughed in; (2.) upon stiff and deep land, that are capable of retaining the valuable matters contained in the manure, and are also physically improved by the decay of the straw and other organic matter. On the other hand, it is not advisable to plough in manure in the autumn, when by so doing it is brought into close proximity with rock, gravel, or coarse sand. When yard manure is applied in the spring it should be well rotted, so as to be at once available for the use of the crop, and to avoid drying the soil and rendering it hollow.

Management of Dung-heaps.—The making of dung-heaps is a winter operation. As dung and litter accumulate under cattle to an inconvenient depth, it is removed. Frosty weather (when land is too hard to plough, and hard enough to bear the pressure of carts) is chosen for the job. The site of a manure-heap is chosen either in the corner of the field for which it is destined, or on a roadside or vacant spot set apart for the purpose. The foundation is best of clay, or tolerably retentive soil; and a few inches depth of peat, of potato haulm, or even of weeds and rubbish, carted off the neighbouring land, makes a good bottom, and absorbs any liquid that otherwise might waste. To this prepared site the dung is carted and spread, taking care that the roughest or most strawy portion is turned into the middle of the heap. If in early winter, the usual course is to cart on to and over the heap, taking care to drive completely over it, and avoiding turning upon it, as a dangerous proceeding for the horses. By this plan, air is to a great extent excluded; fermentation and decay take place slowly. When the heap is finished, the long ends (fig. 11) may be cut down with a dung-knife, and thrown up, so as to form a neat rectangular heap.

If the dung is carted out late in winter or early in spring, it will be required for almost immediate use, and

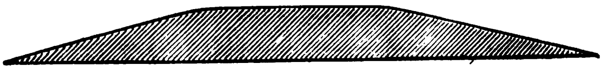

Fig. 11.

in this case it is thrown up out of the carts with the design of promoting a rapid decomposition. Dung-heaps are neatly formed into rectangular, well squared-up heaps of about one yard high when settled; and to obtain this result they should be raised four or five feet high at the outset. Careful farmers cover their manure-heaps with about six inches of earth, or better still, of peat, and sometimes they form it with a view to its throwing off water by making it hog-backed.

All dung intended for spring use should be once—but only once—turned. Commencing at one end, the entire mass is turned over from B to A, fig. 12, the men working in the trench C. After turning, the heap quickly subsides

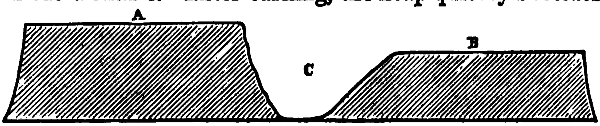

Fig. 12.

and ferments, and in a month's time it will be found to be composed of a black mass, which will cut with a spade.

CHANGES ACCOMPANYING THE ROTTING OF FARMYARD MANURE.—These changes have been carefully noted by Voelcker. They consist (1.) in loss of weight, which amounts to from one-third to one-half, and even two-thirds of the entire mass of fresh manure, according to the degree to which the processes of decay are allowed to proceed; (2.) the quantity of valuable matters existing in a soluble state are materially increased; (3.) the proportion of nitrogen, and other of the most valuable constituents, is increased. The following analysis of fresh,

long manure, composed of cow and pig dung, and of well-rotted dung that had been kept in the heap for six months, will show at once the composition of farmyard manure, and the nature of the changes induced by fermentation:

Table showing the Composition of Farmyard Manure.

	Cow and Pig Manure, long or fresh.		Well-Rotten Dung, six months in heap.	
Water,		66·17		75·42
Soluble organic matters,[1]		2·48		3·71
Soluble inorganic matters—				
Silica,	0·237		0·254	
Phosphate of lime,	0·299		0·382	
Lime,	0·066		0·117	
Magnesia,	0·011		0·047	
Potash,	0·573		0·446	
Soda,	0·051		0·023	
Chloride of sodium,	0·030		0·037	
Sulphuric acid,	0·055		0·058	
Carbonic acid, and loss,	0·218		0·106	
		1·54		1·47
Insoluble organic matters,[2]		25·76		12·82
Insoluble inorganic matters—				
Soluble silica,	0·967		1·424	
Insoluble silica,	0·561		1·010	
Oxide of iron, alumina, and phosphates,	0·596		0·947	
Containing phosphoric acid,	(0·178)		(0·274)	
Equal to bone earth,	(0·386)		(0·573)	
Lime,	1·120		1·667	
Magnesia,	0·143		0·091	
Potash,	0·099		0·045	
Soda,	0·019		0·038	
Sulphuric acid,	0·061		0·063	
Carbonic acid, and loss,	0·484		1·295	
		4·05		6·58
		100·00		100·00
[1] Containing nitrogen,	0·149		0·297	
Equal to ammonia,	0·181		0·360	
[2] Containing nitrogen,	0·494		0·309	
Equal to ammonia,	0·599		0·375	
Total nitrogen,	0·643		0·606	
Equal to ammonia,	0·780		0·735	

To produce the best quality of Farmyard Manure.—From what has been advanced, it may be concluded that the best quality of farmyard dung is made under cover, by fatting cattle fed upon a liberal diet, in which oil-cakes form an important item. Further, that the thorough mixing of the various kinds of dung is most advisable; and if made into heaps and turned, that every means should be used to prevent the escape of nitrogen.

Application of Farmyard Manure, and Quantity available.—If the supply of dung were limitless, there would be but little demand for other fertilisers. There is, however, a limit, and it is found in the amount of straw and fodder available. As a guide, an acre of straw will produce 4 times its weight of fresh manure, or 2·75 times its weight of rotten dung. Since taking wheat, barley, and oat straw together, 1 ton per acre is not an unreasonable estimate, 4 tons of fresh and 2·75 tons of rotten dung for every acre of straw may be looked upon as a sufficiently close estimate of the amount of dung produced upon a farm. If so, 400 acres of arable land, growing annually 200 acres of corn, would give 800 tons of fresh or 550 tons of rotten dung in the year, and allowing half to be rotten and half fresh, 675 tons per annum of farmyard manure. Estimates may also be based upon the head of stock maintained. Mr Baldwin, after repeated trials at Glasnevin, found 1 ton per month to be the amount from fatting cattle in winter; 8 to 10 pigs were found to be equivalent as manure producers to 1 bullock. Mr Stephens considered a horse should make 12 tons of manure in a year, and that an ox should leave 12 tons of manure after seven months' winter feeding, which seems high.

Application of Farmyard Dung.—How to apply this valuable material, is a question of great importance. The usual plan is to manure the section set apart for the cultivation of roots and green crop, or what may be called the fallow crops. According to this system, the land is only dunged once in four years, if, indeed, there is dung

enough to dress all the fallow crops even moderately. Where the four-course system of cropping is pursued, a better plan is to manure twice in the rotation, first for roots, and secondly, upon the young seeds. A dressing of dung in winter or early spring upon young seeds is sure to tell upon the hay crop; and it is a matter of observation that a good crop of clover-hay is likely to be succeeded by a good wheat crop. This is accounted for by the accumulation of the clover root in the ground, and the dressing of the surface with the clover leaf. Thus the land is in a better state for wheat after a good than after a poor crop of clover, and a better crop is the consequence. We may almost say that dung applied to young seeds acts twice, or that it acts upon the clover and reacts upon the wheat.

If we apply a modicum of our manure to seeds, we shall certainly have to select a portion of our root land as specially requiring the remainder. First, all root crops intended to be drawn off the land should be manured with dung. Thus potatoes, mangel-wurzel, and swedes to be drawn home, should be dunged. As a rule, root crops near the buildings are drawn for feeding purposes, and carting is saved if such land is made the recipient of farmyard manure produced at the buildings. Distant fields, where the nature of the soil will admit, are treated with artificial manures alone, and the roots are consumed on the ground by sheep. By this method, carting of manure or of roots to long distances is avoided, and the fertility of the land is maintained.

The relative merits of autumn and spring manuring have been already discussed. When dung is applied in hot weather, as in June for turnips, it should be spread and ploughed in *at once*, whether by common ploughing or ridging, as its efficacy is much impaired by drying in the sun. This liability constitutes an objection to the use of dung upon light soils in dry seasons, the dung often doing harm by leaving the land hollow, and liable to be

injured by drought. On the other hand, in manuring for wheat in the autumn, as is often done in Lincolnshire, the drying of the dung is not objected to, because it recovers its "nature" during the winter.

Dung is applied at almost every period of the year. To young seeds in January and February; to potatoes and meadows in March; mangel and kohl rabi in April; turnips and swedes in May, June, and July; bare fallows in July; old seeds, for wheat, in July and August; winter vetches, rye, cabbages, etc., in September; in October, November, and December, in anticipation of next year's root crop. The quantity usually applied varies with the species and condition of the crop, and the supply; but the following figures may be considered as fairly representing ordinary practice:

	Tons per Acre.		Tons per Acre.
Swedes, . . .	20 to 30	Vetches or rye, .	12 to 15
White turnips, .	15 to 20	Young seeds, . .	12 to 15
Mangel-wurzel, .	20 to 30	Old seeds (for wheat),	12 to 15
Cabbages, . .	20 to 30	Fallow (for wheat), .	15 to 20
Potatoes, . .	18 to 20	Beans, . . .	12 to 15
Cabbages, . .	20 to 30		

COMPOSTS may be defined as the collected rubbish of the farm mingled with lime, in the proportion of about 5 to 1.

Trimmings and clearings of ditches, hedge clippings, road scrapings, stinking stuff from pond bottoms, couch and weeds raked off the land, potato haulm, dead animals, anything in short, of vegetable or animal origin, may be converted into valuable manure. There is no better sign of tidy and thrifty farming than large collections of such like materials on roadsides and vacant spots.

When composts are formed of dead animals, or of animal matter, such as refuse from slaughter-houses, glue-works, fisheries, etc., lime should be avoided, and earth alone be used to prevent the escape of ammonia.

Green Crop Manuring.—Another method of restoring to the soil all the necessary constituents of plant food, is by ploughing in growing crops.

Mustard, vetches, lupines, green rye, and occasionally turnips, have been thus ploughed in, and no doubt form a good preparation for a grain crop. Their action is due to the fact that during growth they appropriate mineral constituents and nitrogen from the soil and air. These materials are then restored to the ground in a prepared state, and are soon rendered available as food for the succeeding crop. So far as mineral matter is concerned, the good effect is not due to the importation of new matter into the land, but to the rendering of what was present easily available. Green crop manuring also imports a large bulk of organic matter, containing nitrogen direct from the inexhaustible supply of the atmosphere. The importance of organic matter in a soil is unquestionably great (see p. 26), not only chemically but physically, and hence the high estimation in which this system of manuring has been held.

As an illustration of the manner in which green-manuring may be useful, it has been proposed not only to manure, but to "clean" land by its means. Thus, Mr Peter Love explained a system for cleaning a soil and rendering it fertile by consecutive green crops ploughed in. White mustard (*Sinapis alba*) was employed for the purpose. No crop grows quicker, and it was found practicable to grow and plough in three closely consecutive "smothering" crops of it, the result being that the land was left not only in a fertile condition for the growth of wheat, but free from weeds. They had been smothered by the luxuriance of the mustard, and completely destroyed by the ploughings.

In spite of those advantages, we must consider that the present high price of meat, wool, and dairy produce, indicates the advantage of passing all green food through animals rather than ploughing it in in the green state,

so that in the present state of the markets it cannot be recommended.

SEA-WEED.—On many parts of the coast of Devon, South Wales, Thanet, Durham, Fife, etc., sea-weed is collected after high tides, and applied to young wheat as a top-dressing, or ploughed in, at the rate of 10 to 20 tons per acre. The cellular, as distinguished from fibrous, character of the tissues of these plants cause them to decay rapidly, and to act quickly, while the considerable amount of nitrogen, potash, lime, magnesia, phosphorus pentoxide, and other mineral plant constituents contained, render them valuable as fertilisers. Sea-weed is sometimes composted with farmyard manure.

Before passing to the subject of special manures, it is necessary to mention several other substances, which may be described as general manures. All organised animal or vegetable matter, and all animal excrements, are capable of being employed as manure, and such manures will always possess a complex, if not completely "general," composition. Farmyard manure is only one of the large class of fertilisers of this class, and among the most important of the rest may be mentioned:

Guano, the excrements of sea-birds accumulated for long ages in vast quantities.

Night-Soil and Pondrette (human excrements).

Town Sewage.

Blood.

Flesh and Small Bones of cattle from South America.

Fish, as sprats and refuse from fisheries.

Bones, hair, horn, and skin, although of animal origin, are less general in composition, and must be regarded as owing their value to certain predominating constituents, as phosphorus pentoxide or nitrogen.

Of vegetable products which may be regarded as general manures, there are many. I have already noticed several, such as sea-weed and growing crops, ploughed in. *Linseed-*, *rape-*, *cotton-*, *seed-*, *castor-*, and other descriptions of *cake*, may be regarded not only as rich in nitrogen,

but as containing all the necessary mineral constituents of plants, and, therefore, as concentrated general manures.[1]

WASTE PRODUCTS.—It is in connection with substances of the above class that waste products may be best noticed. These are exceedingly numerous, and it is impossible to give a complete list of them. Wherever animal and vegetable matters are worked up by the manufacturer, there are sure to be refuse, clippings, parings, shavings, or sweepings, and wherever any one of these occur, there is a fertilising substance. They are mostly of animal and vegetable character, and the first are the most valuable, because they are more concentrated in character, and richer in nitrogen. Mineral wastes seldom are of value, although the manufacture of ammonia phosphate from Redonda alumina phosphate, and gas liquor, are exceptions to this rule. Refuse from slaughter-houses, tanneries, glue-works; horn shavings, hair, wool, and woollen rags, fish refuse, whale blubber, saw-dust, various cakes, malt-house sweepings, etc., etc., may all be used for manurial purposes; and, being of animal or vegetable origin, they are of complex character, and well calculated to restore fertility to land.

SPECIAL MANURES.

It is proposed in a future and larger work to consider at length the special action of the various classes of manures upon corn crops, roots, and grass. In the present short treatise it will be impossible to do justice to the large class of materials employed as fertilisers, but our aim must be rather to indicate the principle of their action. In the last section some substances were included which could barely be considered as coming under the designation of general manures—guano, for example, often being defi-

[1] See also Appendix, table of waste products employed as foods.

cient in potash. Similarly, under the class of special manures certain fertilisers approach in complexity the composition of a true general manure.

PHOSPHATES.

Calcium, potassium, sodium, and magnesium phosphates are all of interest to agriculturists; but from our present point of view the first named is incomparably the most important. Calcium phosphate is found in great abundance in the bones of animals, and it is also widely distributed as mineral phosphate and phosphorite. It occurs in very small quantities in all fertile soils, and it forms an important and abundant constituent of the ash of all our cultivated plants. In the cultivation of such ordinary crops as wheat, barley, and oats, no constituent is more largely drawn upon except nitrogen, the supply of which is derived, in a great degree, from the air. Thus, in the case of phosphates, we have a small supply and a great demand, and therefore, according to the *law of minimum* (p. 104), the application of phosphates might be expected to be followed with excellent results.

BONES.—At the commencement of the present century phosphates were applied as bones to pastures and to turnips. They were at that time ground into inch or half-inch bones, and in the case of pasture-land were sown at the rate of from 30 to 35 cwts. per acre, and occasionally as much as 90 bushels were applied per acre to poor land. The effects of this treatment in Cheshire afford well-known instances of the good effects of bones. In the case of Lord Combermere's estate, land was increased in annual value by this means from 10s. to 30s., and from 15s. to 40s. per acre. Similar effects were recorded in Yorkshire and other counties, and as a consequence "boning" became one of the best recognised methods of improving pasture-land.

The reason for these striking effects is not far to seek, for, as the constituents of bone had been constantly removed from these pastures for a long series of years, in

the shape of milk and young stock, it is no wonder that they had become deficient in phosphates.

A bullock of 1000 lbs. live weight, in store condition, contains about 50 lbs. of mineral matter, according to results obtained on a large scale at Rothamsted, by Messrs Lawes and Gilbert. This mineral matter, we may approximately state to have been collected from (at the most) 2 acres of land in three years, or from 1 acre in six years. This would be equal to the loss of $\frac{50}{6}$ lbs. of mineral matter per acre per annum = 8·3 lbs., or to a loss of 33·2 lbs. in four years. On comparing this with the amount of mineral matter removed from tillage fields during a similar period, we find that, although decidedly less, the quantity of ash ingredients removed by grass land is very considerable. If a wheat crop of 28 bushels, and a barley crop of 33 bushels per acre, be taken during four years, the straw being supposed to be returned to the land, the amount of ash ingredients removed will be about 78 lbs. Although the per-acre loss on pasture is probably less than one-half what it is on arable land, it must be remembered that too frequently pastures are left unmanured, while tillage land receives much indulgence.

There is an opinion abroad, which requires to be qualified, that grazing improves land, although all agree that repeated mowing acts injuriously. The marked effect of bones upon land long grazed, taken in connection with the figures just given, are a sufficient refutation to such erroneous views.

The effect of bones upon pastures is by no means uniform; and caution should be exercised before employing them on an extensive scale. Their application is not always followed with a great increase of quantity; but the quality of the herbage is invariably improved by the encouragement they give to the clovers and finer grasses.

Besides calcium phosphate, raw bones contain calcium carbonate and azotysed carbonaceous matter (gelatine). The following analysis, by Anderson, fairly represents their composition:

Water,	6·20
Organic matter,	39·13
Calcium phosphate,	48·95
Lime,	2·57
Magnesia,	0·30
Sulphur teroxide,	2·55
Silica,	0·30
	100·00
Ammonia, which the organic matter is capable of yielding,	4·80

Raw bones are now but sparingly used. Bone-ash and animal charcoal containing from 70 to 80 per cent. of phosphates, and boiled bones from the soap-works, are largely employed in the manufacture of superphosphate.

Bones which have been deprived of their organic matter by boiling or burning are more suitable than raw bones for the home process of dissolving with sulphuric acid. They dissolve rapidly and completely, while the organic matter of raw bones carbonises and forms an impenetrable envelope around each fragment, preventing the further action of the acid. The following plan is often pursued by agriculturists in the home process of dissolving bones: A ring of ashes is made on the ground of sufficient dimensions. The bone ash, or crushed bones, are then placed in the enclosed area, and moistened with a sixth or fourth of their weight of hot water. From a third to a half of their weight of sulphuric acid of specific gravity, 1·7, is then poured over them, and the mass is moved with rakes until the effervescence ceases. It is then allowed to stand for a few days, and if not dry enough, peat, sawdust, or any substance free from lime may be added to dry it. This process is employed by many farmers, who prefer to buy genuine bones undissolved, that they may know what they are using. Of late years, however, the diffusion of chemical knowledge has given an excellent safeguard from deception, in analysis. It will also be found that home-made super-

phosphate is less finely divided, and inferior in condition for drilling than that made in factories.

CALCIUM PHOSPHATES—"SUPERPHOSPHATE."

The action of bones is greatly accelerated by converting them into "superphosphate of lime." A large number of minerals, rich in insoluble phosphates, may be similarly treated, with the effect of producing substances abounding in soluble phosphates, and highly beneficial to the land.

"Mineral superphosphates" have, in a great measure, superseded the older "dissolved bones," so that "bone superphosphate," pure and simple, is difficult to obtain.[1] The sources from which mineral superphosphates are manufactured at the present day are numerous. In England "coprolite diggings" are met with in Cambridgeshire, Suffolk, Norfolk, Beds, and Bucks. Nodules, scarcely distinguishable from, but on the whole inferior to, those of our eastern counties, are found in France, near Boulogne, and superior sorts are dug in the valley of the Rhone, near Bellegarde, and also in the Ardennes. Russia also possesses in the department of Koursk immense coproliferous beds, abounding in nodules, resembling those found in Bedfordshire. Coprolites may be described as extremely hard phosphatic concretions or nodules, believed by their discoverer, Dr Buckland, to be the fossil dung of extinct animals. They are brown, dark grey, or greenish black, in colour. Various phosphatic fossils of extinct organisms are now classed under the name of coprolites, whose composition renders them valuable to the manufacturer. They consist of terebratula, belemnites, ammonites, and echinodermata, in a more or less perfect state. The percentage composition varies within wide limits, but all abound in phosphorus pentoxide, lime, ferric and alumina oxides, carbonic acid, and occasionally a trace of organic matter.

[1] Many so-called "bone superphosphates" contain a very high percentage of mineral phosphates.—J. W.

The general composition of English coprolites, according to a recent analysis by Voelcker, is as follows:

Moisture,	2·30
Water of combination,	1·50
Phosphorus pentoxide,[1]	26·05
Lime,	43·68
Ferric and alumina oxides,	18·70
Insoluble silicious matter,	7·77

[1] Equal to tricalcic phosphate of lime, 56·87.

Among other sources of mineral superphosphate may be mentioned the following:[2]

1. *Welsh or Silurian Phosphate* occurs not far from the lead-bearing clay slate of Llangynag, and in other parts of North Wales. The mineral occurs as a phosphatic limestone, 8 feet 6 inches to 9 feet thick, and as a black shale, fully 18 inches thick. The quality is very variable, and the difficulty of separating the rich from the worthless is a serious difficulty in working them; nevertheless, the Silurian phosphate has, to some extent, made its way into the hands of manufacturers (Voelcker).

2. *Canadian Phosphorite* occurs in fissures of granitic rock, generally associated with gneiss or mica slate. It appears to occur in six-sided prismatic crystals of light green colour, glass-like lustre, and brittle texture. Good samples contain 70 to 72 per cent. of calcium phosphate, and although somewhat hard and difficult to reduce to a fine powder, a few cargoes find their way to England in the course of the year.

3. *Spanish (Estremadura) and Portuguese Phosphorite* are very valuable minerals, yielding in many cases phosphorus pentoxide equivalent to the production of 76 to 86 per cent. of tricalcic phosphate. The Portuguese mines are said to be inexhaustible, but up to the present time they have not been worked to a profit for want of

[2] For more detailed information see Dr Voelcker's papers upon "Phosphatic Materials used for Agricultural Purposes," Royal Agricultural Society's Journal, vol. xxi., p. 350, and vol. xi., 2d series, p. 399.

roads. These minerals are either white or slightly yellow in colour, crystalline, often veined with quartz, and of variable hardness.

4. *German Phosphate* occurs in the duchy of Nassau, and is known in England as Nassau and Lahn phosphate.

5. *French Phosphate.*—Of late years large quantities of phosphatic minerals have arrived from the valley of the Lot, a tributary of the Garonne, in the south of France. They are known as French or Bordeaux phosphates. Both the French and German phosphates occur in "pockets," rather than veins or beds. According to Voelcker, the quality of imported phosphates from both countries has declined of late years, either from the exhaustion of the richer beds, or the impetus of an increasing demand causing inferior beds to be worked.

6. *South Carolina or Charleston Phosphates* closely resemble the coprolites of the London basin, and have been discovered in large quantities. They occur as a remarkable bed, 12 to 18 inches thick, known to geologists as the "Fish Bed" of the Charleston basin. The bed consists of indurated irregular-rounded nodules, often buried in an adhesive blue clay. Associated with these is a wonderful assortment of animal remains. The workable area is stated to be from 40 to 50 square miles. The Charleston phosphates make a good superphosphate, and are rather more valuable commercially than the Suffolk or Bedfordshire coprolites. The supply from Charleston is divided, according to the position in which they occur, into "land" and "river" phosphates. Both are of good quality.

7. The islands of Sombrero, Navassa, and Aruba, in the Caribbean Sea, and of St Martin, in the West Indian Sea, all possess phosphatic deposits of a shelly or rocky character.

8. Peculiar phosphatic minerals are found on the Redonda Island and Alta Vela Rock, composed of crude phosphate of alumina. The absence of lime prevents its being used in the manufacture of superphosphate, but it

is employed in the production of alum, and as a by-product the impure phosphoric acid is converted, with the aid of ammonia and other fertilising materials, into artificial manure. Redonda and other crude alumina-phosphates are employed in the clarifying of town sewage.

COMPOSITION OF SUPERPHOSPHATES.—The extent to which this class of manures is employed may be gathered from the fact that about 5,000,000 acres of turnips, swedes, mangel, and kindred crops, are annually grown in Great Britain, and that superphosphate is almost universally employed in their cultivation, and ordinarily at the rate of from 2 to 4 cwts. per acre. Superphosphates also form the basis of many manures sold under such titles as "potato manure," "cereal manure," "grass manure," etc., so that the amount annually used must be represented by at least 300,000 tons. It is therefore evident that bones could never furnish the requisite material for the manufacture of superphosphate, and the importance of good mineral phosphates is rendered evident. From whatever source derived, the manufacture of superphosphate depends upon the existence of two different combinations of calcium with phosphorus pentoxide. In bones and the mineral substances enumerated, the phosphorus pentoxide is united with three equivalents of calcium, forming an insoluble salt, known as *calcium phosphate*, or tricalcic phosphate. Sulphuric acid (sulphur teroxide) is employed to break up this combination, which it does by seizing upon two of the three equivalents of lime, converting them into gypsum or calcium sulphate, while the remaining equivalent of lime continues united to the phosphorus pentoxide as monocalcic (soluble) phosphate. The change may be thus expressed in chemical symbols:

$$\underset{\text{Insoluble tricalcic phosphate.}}{Ca_3 2PO_4} + \underset{\text{Sulphur teroxide.}}{2H_2SO_4} = \underset{\text{Soluble monocalcic phosphate.}}{CaH_4 2PO_4} + \underset{\text{Calcium sulphate.}}{2CaSO_4}$$

Since the substances employed contain besides calcium car-

bonate, salts of iron, etc., much of the sulphur teroxide is diverted from the purpose for which it is added, and absorbed in converting such carbonates into sulphates. Raw or unboiled bones require one-third of their weight of sulphuric acid of sp. gr. 140° (Twaddell). It is, however, seldom that raw bones are employed by the manufacturer. The fat and gelatine contained in bones is worth preserving, and not only so, but if unremoved, their presence checks the action of the acid upon the bone. Boiled bones, bone-ash, and bone-black or animal charcoal, are therefore more usually employed. These substances require from one-third to one-half of their weight of sulphuric acid to convert the whole of their insoluble phosphate into the soluble monocalcic salt.

When coprolites or mineral phosphates are employed in the manufacture of superphosphate, sufficient acid must be added to first neutralise the carbonates, and then to act upon the calcium phosphate. From one-third to one-half of the weight of the coprolite will usually be sufficient.

The quality of superphosphates will vary according to the source from which they were derived, and the quantity of acid required. The composition of mineral superphosphate is shown in the following analysis of Lawes' mineral (coprolite) superphosphate by Professor Church:

Water,	12·58
[1] Organic matter and water of constitution,	15·35
[2] Monocalcic phosphate,	19·47
Tricalcic phosphate,	7·59
Calcium sulphate,	37·47
Silica,	4·07
Alkalies, iron, etc.,	3·47
	100·00

[1] Containing traces only of nitrogen.
[2] Equal to 25·79 of bone-earth rendered soluble.

Analyses by the late Dr Anderson of superphosphates manufactured from bones and bone-earth, gave respec-

tively 10 to 13 and 21 to 23 per cent. of monocalcic phosphate.

The following analyses, two of bad, and one of a good superphosphate, were made by Dr Voelcker, and published in his annual report as consulting chemist to the Royal Agricultural Society (1876):

COMPOSITION OF THREE SAMPLES OF ARTIFICIAL MANURES.

	No. 1.	No. 2.	No. 3.
Moisture,	17·46	18·38	10·28
Water of combination and organic matter,	18·82	25·51	22·65
Biphosphate of lime (monocalcic phosphate),	4·97	6·45	18·91
Equal to tricalcic phosphate rendered soluble,	(7·79)	(10·10)	(29·60)
Insoluble phosphates,	7·29	17·60	12·05
Calcium sulphate, alkaline salts, and magnesia,	35·17	28·96	32·06
Insoluble silicious matter,	16·29	8·15	4·10
	100·00	100·00	100·00
Containing nitrogen,	·88	·68	1·66
Equal to ammonia,	1·07	·83	2·02

The comparative money value, according to the preceding analyses, is:

For No. 1,	£4	0	0	per ton.
,, No. 2,	4	10	0	,,
,, No. 3,	9	5	0	,,

The price at which they were actually sold, delivered, carriage paid, at the nearest station, was:

No. 1,	£7	10	0	per ton.
No. 2,	7	5	0	,,
No. 3,	8	0	0	,,

FUNCTIONS OF PHOSPHATES—*In the Plant.*—The pre-

cise mode of action of any ash ingredient is difficult to trace, and may be said to be as yet imperfectly known. (1.) According to Schumacher, potassium phosphate considerably increases the diffusive rate of albumen, and thus facilitates its movements in the plant.[1] If this is a true explanation of at least one function of the phosphates, we must further premise that a decomposition takes place by virtue of the vital functions of the plant, whereby calcium phosphate is converted into potassium phosphate. (2.) The phosphorised oils require phosphorus for their elaboration. (3.) Phosphates, in common with other ash ingredients, co-operate in the organisation of the proximate constituents of plants, such as glucose, dextrine, and starch. These substances are elaborated in the foliage, and are subsequently diffused to every active organ of the plant.[2] All seeds contain a considerable proportion of it, a fact which points to the conclusion that it is required in the early stages of life, and probably acts at that time in promoting the locomotion of the albumen of the seed.

The addition of superphosphate to a field acts powerfully upon turnips, swedes, and other root crops. Its effects are not very evident upon wheat, but it has been noticed to exert a favourable action upon barley, especially when late sown. From what we know of the requirements of plants, we might naturally think that turnips and barley must require a large amount of phosphates, and that wheat had not similar need. This conclusion would be erroneous. For although a root crop certainly does remove more phosphates from a soil than a crop of wheat, a barley crop, practically speaking, requires about the same amount. A fair crop of wheat, of 32 bushels, removes in corn and straw about 26 lbs. of phosphorus pentoxide from the soil. Twenty tons of turnips, with their tops, take about 40 lbs., so that a crop of turnips needs 14 lbs. more than a crop of wheat (Voelcker). Wheat then undoubtedly requires a large amount of this ingredient; and considering its much

[1] "How Crops Grow" (Macmillan & Co.). [2] *Ibid.*

less weight per acre, it is proportionally richer than turnips in this element. Why then should phosphates act strongly upon turnips and barley, and scarcely at all upon wheat? The main reason appears to be the long period during which wheat occupies the ground, and the amount of space covered by its roots. *A manure is never useful unless it is wanted*, and there is usually enough phosphorus pentoxide in good wheat lands for this crop, considering the length of time the plant is engaged in its search. The addition of more of this constituent therefore becomes superfluous in all such cases.[1] With barley and roots it is very different. They both grow rapidly, and depend upon a thinner stratum of soil for their nutrition, hence they at once seize upon and utilise any fresh supply of *the least abundant, and therefore most important*, of the essential ash ingredients.

The effect of superphosphate upon the root crop is certainly remarkable. In many districts 3 cwts. per acre is found a sufficient application. This will represent 31 lbs. of phosphorus pentoxide, if the manure contain 20 per cent. of soluble or monocalcic phosphates. But, supposing the turnip crop yields 20 tons per acre, it will have removed 40 lbs. of this ingredient, so that it will have not only used all that was contained in the superphosphate, but drawn upon the natural resources of the soil to the extent of 9 lbs. This can only be accounted for by the increased energy conferred upon the plant, in the early stages of its growth, by the superphosphate, which gives it the power to thrive and send its roots in search of the mineral constituents native to the soil.

Although superphosphate is the best manure for swedes and turnips, it occasionally happens that it produces but little effect. The cases in which disappointments occur have been thus classified by Dr Voelcker:

1. If the phosphates are washed out with heavy rain or undergo changes which render them ineffective.

[1] When a soil is deficient in phosphates, phosphatic manures may be expected to act beneficially even upon wheat.—J W.

2. If the soil contains a sufficient supply of phosphates, when an additional supply can be of no avail.

3. If the soil is deficient in potash or other essential ash ingredients, in which case phosphates alone could not produce a result.

With respect to the first case, it is necessary to refer to page 30, where the peculiar power of fertile soils, to remove, fix, and retain the most important ash ingredients from solution is noticed. It is probably seldom that phosphates are washed through a soil, although there is a considerable difference in the absorptive and retentive powers of soils with regard to them. Experiments on a small scale have shown that soils containing lime take up phosphates most quickly from solution, and fix them beyond the power of rain to wash them further. Stiff clays and sandy soils do not possess this property to nearly the same extent; but when a moderate dressing of superphosphate is exposed to the action of the entire mass of soil, it may be expected that those possessed even of the feeblest absorptive power will be able to prevent the soluble phosphate from washing through.

The absorptive power of soils is not exercised instantaneously, but gradually. When therefore a superphosphate is distributed in a soil, water will cause the diffusion of the soluble phosphates through the soil, and as it is disseminated, it will be fixed by the soil it comes in contact with. The soluble phosphate therefore becomes once again insoluble. It is, however, by no means in the insoluble condition in which it existed before its treatment with sulphuric acid, but infinitely more finely divided, and, so to speak, *condensed* upon the particles of soil. Although insoluble to a high degree in water, and therefore only with difficulty capable of being washed through the soil, it is soluble in weak acetic acid, and is in a condition to serve in the nutrition of plants. Mineral acids in a very dilute condition have been found highly injurious to vegetation, and we may therefore consider that the neutralisation of the free acid contained in

superphosphate, and the reprecipitation of the phosphate, are beneficial effects.

It is important that this reprecipitation should not take place before superphosphates are sown. If mixed, as was formerly the general practice, with ashes, which are almost always strongly alkaline, the soluble phosphate must be rendered insoluble, and their power of diffusion be consequently checked. The water drill, however, obviates this difficulty, and no doubt one of its most valuable services consists in effecting the distribution of the phosphates in a thoroughly soluble condition, in which state they will be most completely disseminated through the soil.

"REDUCED PHOSPHATES." — Professor Church thus notices the formation of "reduced phosphates," or the reduction of soluble phosphate into an insoluble condition: "It is a well-ascertained fact, that with some phosphatic materials, a portion of the phosphate rendered soluble by the action of sulphuric acid upon them becomes reduced, or goes back once more to the original insoluble or difficultly soluble condition. This is a serious loss both to the manure manufacturer and the farmer. The manufacturer turns out a product which seems inferior to sample and guarantee; the farmer obtains a manure in which perhaps a fifth of the soluble phosphate has lost at all events its diffusive power, and in consequence some of its efficiency. Superphosphates made from raw materials containing much iron seem peculiarly liable to this reduction."

LIME.

Lime has already been noticed as a constituent of all fertile soils, and an ingredient of all cultivated plants. The high proportion in which it occurs in the ash of many plants is sufficient to account for its value as a manure, while its mechanical and chemical effects upon the soil (p. 25) enhance its agricultural value. The following plants yield a preponderating quantity of lime in

their ash, and have therefore been classed as "lime plants."

PERCENTAGE OF LIME IN THE ASH OF CERTAIN CULTIVATED PLANTS:

Potatoes (stem and leaves), .	46·2 per cent.	Red clover, . .	34·0 per cent.
Tobacco, . . .	67·44 ,,	White clover, .	32·2 ,,
Lucerne, . .	48·0 ,,	Sainfoin, . . .	32·2 ,,
Kidney vetch, .	68·9 ,,	Alsike clover, .	31·9 ,,
Red clover, .	39·7 ,,	Vetches, . . .	26·3 ,,

Experiment has demonstrated that lime is absolutely necessary to the development of all plants, and the above list shows how largely it is appropriated by many leguminous and other crops.

APPLICATION OF LIME.—Lime is applied in two conditions—raw and prepared. When applied as marl or chalk it may be spoken of as raw or crude; when subjected to burning or calcining, as prepared.

Marl has already been defined as a mixture of clay and lime. It no doubt acts beneficially by virtue of both ingredients. In Norfolk sandy soils have in many cases been greatly improved by the application of "marl" dug from pits and spread upon the surface. It occurs as blue, grey, red, and yellow marl, of which the first and last are most valuable, and it is applied at the rate of 40 to 80 cubic yards per acre. The composition of marls is very various, some containing 8 and others 80 to 90 per cent. of lime. They have been classified, according to composition, into true marls, or those in which calcium carbonate predominates, and clay marls, or those in which clay is the chief constituent.

Chalk, especially when derived from the formation of the "Lower Chalk," is an exceedingly valuable addition to the strong lands of the London and plastic clays, and in fact to any clay deficient in lime. Along the Essex coast there are special facilities for its application, in the near proximity of chalk, and in the cheap water carriage.

Further inland the farmers prefer lime on account of the lower cost of carriage. Chalk is applied at the rate of 20 tons per acre, and is very effective, and considered more lasting than lime. The effect of chalk is due to calcium carbonate, of which it is almost entirely composed.

Lime is prepared by burning oolitic, magnesian, and mountain limestones. Common limestones (as distinguished from the magnesian variety) contain from 80 to 90 per cent. and upwards of calcium carbonate, small quantities of calcium phosphate and sulphate, silica, iron, alumina, and water. The effect of a red heat is to drive off the carbon dioxide and water, and to leave the limestone in a highly porous state. On exposure to the air, or immersion in water, the water, and to some extent the carbon dioxide, are reabsorbed with the evolution of heat. This is called "slaking," and is accompanied with a crumbling down or "falling" of the fragments of limestone into a fine powder. The rapidity with which lime is changed from the "caustic" or anhydrous into the mild or slaked condition is important. If exposed to the action of an abundant supply of water, the lime is not only reduced to a powder, but may be converted into a paste, which is most undesirable. In order to secure the best effect, the burnt lime or "shells" should be carted into heaps of considerable size upon the headlands of the fields, and covered with a few inches thickness of earth. Treated in this manner, the lime will gradually reabsorb the expelled elements. When a stick can be thrust completely through such a heap without meeting resistance from unslaked lumps of lime, the process is complete, and the powdered lime may be applied. The slower the process, the more completely is the causticity of the lime neutralised.

Lime is employed with most effect (1.) upon soils which are deficient in it, (2.) upon stiff clays, (3.) upon peaty soils, or those containing a large amount of undecomposed vegetable matter. It does not act energetically

upon light soils. Again, on old tillage lands, especially those which have been frequently limed, it exerts but little effect; while upon newly broken up lands it is highly efficacious. There is a general opinion among practical men that lime should be in a highly caustic condition if applied to old tillage lands. Three, six, and nine tons per acre may be considered respectively to represent light, medium, and heavy dressings per acre, and the effect is supposed to last about twelve years.

Gypsum (calcium sulphate) is another form in which lime is employed as a manure. It is occasionally applied at the rate of from 2 to 10 cwts. or more per acre to clover and other leguminous crops. It may also be employed to fix the ammonia in ordinary farmyard manure, by scattering it over the floors of stables and upon manure heaps. Gypsum is an inseparable ingredient of all superphosphates, in which it exists as one of the results of the application of sulphur teroxide to phosphates abounding in lime. A dressing of 5 cwts. per acre of a good superphosphate necessarily involves the application of about 2 cwts. of gypsum.

OTHER MINERAL[1] MANURES.—*Potash salts*, in the form of potassium carbonates, sulphates, chlorides, and silicates, have all been employed as manures with success. The importance of potash is proved by its constant occurrence in the ashes of all cultivated plants. After phosphorus pentoxide, it is the most abundant material in the ash of wheat, and it is the most prevalent ingredient of the ash of beans, turnips, and potatoes. In hay and in straw it is the most important ash ingredient after silica. Potash may therefore be considered as equal in importance with phosphorus pentoxide in the nutrition of plants, and yet there is as yet comparatively little demand for it as a marketable fertiliser. Once more we must refer to Liebig's "law of

[1] The term "mineral" is here employed to express those substances which form the ash or mineral (non-volatile) parts of plants.

minimum" as the explanation of this fact. Potash appears to be sufficiently abundant in most soils to meet the requirements of plants, and until the store is reduced, further additions are superfluous. The practice of returning the straw to the land in the form of manure no doubt tends to conserve the fund of potash. Of 30·81 lbs. of potash removed from the land in an average crop of wheat, 20·7 lbs. are returned in the straw. The high percentage of potash in the ashes of potatoes, hops, and several leguminous crops, such as vetches, clovers, and beans, indicates that it might be employed in their cultivation with success, and experience has proved the truth of this supposition in many cases.

Until recently the great bar to the employment of potash was its high price. Owing, however, to the discovery of abundant sources of potash salts under the name of *kainit*, at Stassfurt, in Prussia, crude potash salts may now be purchased at £4 per ton. The discovery of this abundant source of potash salts was made in the year 1859. During that year the ducal Government of Anhalt Dessau caused a shaft to be sunk at Leopoldshall for the purpose of discovering metals or salts; and when the miners arrived at a depth of about 450 feet, they met with a layer of rock-salt (*stein-salz*), which extended to about 3700 feet in a south-easterly direction towards the Prussian frontier, dipping, however, nearly 400 feet in that short distance. Boring through the surface of the layer, the explorers arrived, in a depth of about 70 feet, at a skim or refuse salt, about 630 feet in depth; and, after boring through this very serious impediment, they discovered an inexhaustible field of rock-salt, extremely rich in valuable potash salts. It is out of this part of the vast layer that carnellit, the material from which muriate of potash (potassium chloride), kieserit, and especially kainit, are obtained.[1]

The composition of a good sample of kainit, analysed by Dr Voelcker, gave the following result:

[1] Messrs Eekhout & Co.'s circular.

Moisture (loss at 212° F.),	3·36
Water of combination,	10·88
Potassium sulphate,	24·43
Calcium sulphate,	2·72
Magnesium sulphate,	13·22
Magnesium chloride,	14·33
Sodium chloride,	30·35
Insoluble silicious matter,	0·71
	100·00

Common salt (sodium chloride) has long been employed as a manure. It may be recommended especially for mangel-wurzel and wheat, and may be applied at the rate of 5 cwts. per acre. The effect produced depends much upon the character of the land. Upon stiff and cold soils it is least effective, while upon warmer and dryer soils it is often beneficial. Common salt may be used with good effect upon pastures which carry a coarse herbage, and is useful to mix with nitrate of soda as an application for wheat. It checks the disposition of the nitrate to unduly promote the growth of straw, and effects a more thorough distribution of the nitrate by increasing the bulk of the dressing.

Sulphate of magnesia has also been recommended as a manure, but it is seldom applied unless for experimental purposes. Like every other substance applied, its efficacy will entirely depend upon the amount of magnesia or other sulphates in the land.

NITROGENOUS AND AMMONIACAL MANURES.—All animal and vegetable manures owe their value in a great measure to the presence of nitrogen in combination. In the living animal or plant, nitrogen exists as a constituent of albumen, caseine, fibrine, legumin, and gluten. In the process of decay and decomposition the nitrogen is released from its organic combinations, and converted first into ammonia, and subsequently into nitric acid. Ammonia or volatile alkali combines with acids, giving rise to ammonium carbonates, sulphates, phosphates, and other salts; the nitric acid combines with bases, and, as

a result, we have nitrates of potash, soda, lime, etc. Nitrogen is applied whenever decaying organised matter, whether plant or animal, is employed as manure, and it is equally valuable when it exists in the form of ammoniacal salts or nitrates.

To give a complete account of all nitrogenous manures would be impossible in so short a treatise as the present. A few of the more important sources of nitrogenous special manures may, however, be mentioned.

Nitrate of soda (sodium nitrate) is imported from Peru, where it occurs in beds, sometimes 7 to 8 feet thick, preserved from solution by the extremely arid character of the climate. The source appears to be inexhaustible. Refined nitrate of soda, as imported, contains only about 5 per cent. of impurities, and may be purchased at from £13 to £16 per ton, according to the fluctuations of supply and demand. Few fertilisers act so rapidly when judiciously applied. Being exceedingly soluble, and therefore liable to be washed through the soil, it should be distributed over the land in March and April, just at the time active vegetation commences. It exerts the strongest influence upon gramineous herbage of all kinds. Hence it is very beneficial to wheat and the other cereals, to Italian rye-grass, and all pasture and meadow grasses. In this respect its action resembles that of all nitrogenous and ammoniacal manures, which invariably stimulate the growth of grasses and cereals. The quantity applied is small, 84 to 112 lbs. being sufficient for 1 acre of land. The effect is speedily seen in the darker colour of the foliage a very few days after the application, the rapid development of the plant, and, in time, a more abundant crop. Nitrate of soda acts more powerfully upon the leaf and stem than upon the flower and fruit; but that it also acts upon the grain has been frequently proved. The increase from its use has sometimes amounted to from 10 to 12 bushels per acre; and in experiments undertaken by the author in 1871, 4 to 4½ bushels of wheat were in several cases obtained from the

use of 100 lbs. of the nitrate. When applied to "roots," it should be employed with care, as, if brought in contact with the seed, the nitrate is apt to injure its vitality. If distributed broadcast over swedes, just before the second hoeing, it exerts a very beneficial effect.

Nitrate of potash (saltpetre) has long been known as a manure, but its high price has greatly restricted its use, and nitrate of soda has completely taken its place.

Sulphate and muriate, or chloride of ammonia (ammonium sulphate and chloride) are very potent manures when applied to the cereals and grasses at the rate of from 1 to 1½ cwts. per acre. *Soot* owes its manurial action to the presence of a small percentage of ammonium sulphate.

Guano.—Although guano has been mentioned among those excrementitious substances of complex character of which farmyard manure is the type, it is impossible to omit noticing it as one of the most popular nitrogenous manures. It is scarcely necessary to mention that guano is altogether derived from the dung of sea-fowl. The most famous source of it is Peru, where it occurs between the 13th and 21st degrees of south latitude, both on the mainland and on the numerous islands and rocks which are sprinkled along this part of the coast of South America.

The dryness of this region has preserved the soluble, and especially the ammoniacal ingredients of the guano, but it has been found that the quality and composition of guanos varies greatly with the climate. When deposited in dry regions, good samples contain 17 to 20 per cent. of ammonia, although recently many samples have been forwarded to this country containing only from 8 to 12 or 13 per cent. So wide are the limits of variation that guano should be purchased with caution, and the judgment should be guided by chemical analysis.

Peruvian guano is sold at about £14 per ton, and must be regarded as a most valuable substance. It is particularly esteemed in the north of England, Scotland, and Ireland, where the coolness and humidity of the climate

favour its action. In the southern counties guano gives way to superphosphate to a very considerable extent. In districts favourable to its use, it is applied with good effect to the root crop, in combination with superphosphate, 1½ to 2 cwts. of guano with 3 to 4 cwts. of superphosphate being considered a sufficient dressing for one acre. Where portable manures are sown with the dry or the water drill, it is not advisable to employ guano, as it is apt (like nitrate of soda) to destroy the vitality of turnip and swede seed. The guano should, in such cases, be sown upon, and worked into, the land with harrows and cultivators, before the seed is sown with the superphosphate.

As a top-dressing for young corn it is highly esteemed, especially in the northern counties; and it is universally employed as a means of improving pastures. Two hundredweights per acre is a sufficient quantity for a top-dressing.

The accompanying table will show the general composition of various sorts of ammoniacal guano. The first two examples are remarkably fine guanos from Angamos, analysed by Dr Voelcker, and pronounced by him to be considerably richer in nitrogen than the best Cincha Island guano he had ever examined. The third example shows the composition of a good Peruvian guano. The fourth and fifth are both from Guanape Island, and are inferior to those previously given. Phosphatic guanos contain very small quantities of ammonia, and a high percentage of phosphates. Thus Mejillones guano contains from ·87 to 1·19 per cent. of ammonia, and phosphorus pentoxide equal to from 64 to 77 per cent.

TABLE SHOWING THE COMPOSITION OF GUANOS RICH IN AMMONIA.

	Angamos.		Peruvian.	Guanape Island.	
	No. 1.	No. 2.		No. 1.	No. 2.
Moisture,	7·24	8·76	13·73	17·79	20·10
Organic matter and salts of ammonia,[1]	69·01	69·96	53·16	42·62	38·67
Phosphates,[2]	12·06	12·07	23·48	25·45	32·53
Alkaline salts,	9·02	8·27	7·97	11·92	5·97
Insoluble silicious matter,	2·67	0·94	1·66	2·22	2·73
	100·00	100·00	100·00	100·00	100·00
[1] Containing nitrogen,	21·15	19·30	..	10·04	7·87
Equal to ammonia,	25·68	23·44	17·00	19·19	8·95
[2] Containing soluble phosphoric acid,	Not determined	3·01	..	4·75	3·19
Equal to tribasic phosphate, rendered soluble by acid,	..	6·57	..	10·37	6·98

PHOSPHATIC GUANOS.—Where the droppings of the sea-fowl have been exposed to the action of rain, or sea water, the soluble portion has disappeared, and the phosphates and other insoluble matters have been left in the form of a compact shelly or rocky material.

Most phosphatic guanos contain from ·5 to ·75 per cent. of nitrogen, and frequently phosphorus pentoxide, equal to the production of 75 per cent. or more of tricalcic phosphate. Such are the guanos from Mejillones Bay, Raza Island, and other islands in the Gulf of California; Curaçao Island, off the coast of Venezuela; Baker Island, in the Caribbean Sea, and many other places. These guanos are not suitable for direct use, but are readily converted into superphosphate by the addition of sulphuric acid.

Phospho-guano is artificially formed by treating guanos of phosphatic character as just indicated, and forms a valuable fertiliser.

PART III.

ROTATION OF CROPS.

General Conditions necessary to Successful Cultivation.

A soil well stocked with the necessary ash ingredients of plants, and nitrogen; in a good physical condition; situated in a good climate, and possessing a good subsoil, and a favourable aspect, are the necessary conditions of fertility. Each of these conditions has occupied attention in the previous pages, and our next study must be that of those general principles which should be observed in order to secure the best crop with the least possible injury to, or the greatest possible improvement of, the land.

Rotations.

The idea of an orderly succession of crops is no doubt ancient. It was rigidly carried out in the cultivation of the *Arable Mark* or common lands (Folcland) of the old Saxon village community. The whole arable mark was usually divided into three fields, each field lying fallow once in three years; one-third part to be sown with winter grain (wheat), one-third with summer grain (oats, barley, or beans), and one-third to be bare fallow. According to Professor Rogers of Oxford, such was the usual division of land in the thirteenth century throughout England. A high antiquity is accorded to this system by Mr R. B. Morier when he speaks of it as one important

aspect of the early Teutonic freeman even so far back as the first century. How the idea of a rotation first originated may be readily guessed from the fact that the practice of growing a particular kind of crop year after year on the same land cannot be carried on long without evil effects. A limit has been reached, even in many of the most fertile soils of the New World, where wheat and tobacco cannot longer be grown profitably.

The first result of the exhaustion of land in a more or less nomad condition of society would be the migration of the cultivator to fresh fields, and the relinquishing of the worn-out lands to natural pasture. This in itself would be rest, and it is not necessary here to go over the reasons already given (p. 32) for the gradual recovery of such relinquished lands. Suffice it to say that fertility would in time return to them, and they would once more be capable of remunerative cultivation. This in itself would be a sort of rotation or alternation between a series of years in corn, and a series of years in pasture. Convenience would suggest the advantage of sowing one portion of the land with spring corn and another with winter corn; and systematic working of fallows would shorten the period necessary for renovating an exhausted field; and the three-field course would thus gradually shape itself, and all the more readily as the increase of population rendered better cultivation imperative.

Bearing in mind the disintegrating forces that are always at work in a soil, the benefits of a fallow no longer remain a mystery. What might require years to produce, if the soil were left entirely to nature, is accomplished in a single season by the pulverising and aerifying effects of tillage implements, assisted, as they invariably are, by the action of the atmosphere, moisture, and changes of temperature.

The benefits of a fallow were known to the Israelites, who were required to fallow all their land once in seven years. The Romans introduced the practice into this country; but a systematic tillage of bare fallows is said

to have been unknown in Scotland till about a hundred years since. The old three-field course is still practised in certain stiff land districts. It consists in taking a crop of wheat, followed by beans, oats, or sometimes clover, and the third year it is fallowed. Such a system is not likely to be remunerative at present corn prices, and if a better system of cropping cannot be profitably introduced, such lands ought to be laid away to permanent pasture.

On the better classes of clay lands, bare fallows are made occasionally if a field is exceptionally foul, or when the season is unpropitious for root cultivation. As the quality of the clay land rises, the intervals between the fallows are lengthened as follows:

Poor clays:

Fallow (bare or cropped) : wheat : beans, or oats, or clover.

On *clays of better quality* an additional corn crop is sometimes taken, as for example:

Fallow (bare or cropped) : wheat : beans : oats.

On *richer clays*, as those of Holderness, in south-east Yorkshire:

Fallow (bare or cropped) : wheat : beans : wheat : clover : wheat.

On the *richest clays* even longer rotations are practised, as for example on the Carse of Gowrie, where the following course of cropping has been adopted:

Fallow : wheat : barley : clover : oats : beans (dunged) : wheat.

This last must be looked upon as "scourging," and cannot be recommended, except upon a restricted class of land.

PRINCIPLES ON WHICH ROTATIONS ARE CONSTRUCTED.

A clear view of the principles which should guide an agriculturist in constructing rotations will be best ob-

tained by dividing all soils, in the first place, into heavy and light, or stiff and free. The treatment of these two classes of soils is about as opposite as it well can be.

Stiff soils are essentially suitable for corn or grain crops. Hence in the foregoing examples of rotations it will be found that the proportion devoted to grain in some form is respectively $\frac{2}{3}$, $\frac{3}{4}$, and $\frac{5}{7}$. Such lands are called "wheat and bean land," because they are most suitable for these crops. They are unsuitable for the growth of turnips and swedes for two reasons. *First*, the difficulty and expense of obtaining a sufficiently fine tilth in the spring and early summer; *secondly*, because it is troublesome, and often injurious, to cart off the produce in the autumn, and certainly injurious to consume it upon the land during winter. The underlying reason for both of these difficulties is the plastic character of clay soils. They must be lightened up, being already too close in texture. It is fatal to success to plough or work them when wet, and consequently carting or folding sheep upon them in winter is sure to be followed by a diminished wheat crop the succeeding year. Now, as the turnip and swede crop are grown with the idea of *improving* land, and causing it to grow a better corn crop, it is evident that on these stiff soils their cultivation cannot extend. There are, however, other fallow crops which may be grown upon clay lands. All forage crops which are eaten by live stock during the dry months, and are cleared off in time for wheat sowing in the autumn, are fit for clay soils. Such are winter and spring vetches, rape, cabbages, kale, early white turnips, and kohl-rabi. All these crops are ready for use from May to the end of September or October. Stiff clays should, for the same reason, be manured with long or fresh manure, so that the decay of the straw and fermentation of the dung may open up and divide the soil. Autumn ploughing for fallow crops is also advisable, that the pulverising effects of the winter's frost may be thoroughly realised.

Free soils are suitable for turnips, swedes, and forage crops in general. They are defined in farming phraseology as "turnip and barley soils," because they grow both crops to perfection. It will be found that one-half of the arable land is usually devoted to each purpose, *i.e.*, corn and fodder crops. They are suitable for turnips, as they are readily reduced to a fine tilth, and because the treading and manuring of the sheep in winter is the best preparation for a grain crop. A policy of *consolidation* is to be noticed throughout the course of cropping. They are often intentionally ploughed wet for corn; the leas are heavily rolled or land-pressed before wheat is sown; the young corn is also rolled in the spring to press the soil around the roots; and the manure is preferred well rotted. Such land is ploughed shallow for grain, and stubble and haulm or weeds are raked together and burnt rather than ploughed in. All these precautions have one end in view, namely, preventing "hollowness" and promoting firmness.

General Effects of Corn, "Root," and Forage Crops upon the Land.

Corn crops exhaust the land (1.) because they are sold off the premises; (2.) because on account of the narrow spaces between the rows, and the length of time they occupy the land, they do not allow of the thorough destruction of weeds. Land long under corn crops is apt to become both poor and foul.

Root crops are well calculated to take the place of the old bare or naked fallow on a large class of soils. (1.) They are not sown until May, June, and July; and, therefore, allow ample opportunity for cultivation from the securing of the previous corn crops in August or September until the next summer. (2.) They do not thrive unless the land is fine and well manured. (3.) They are sown at wide intervals, and constantly hoed and kept clean during their growth. (4.) They are consumed upon the

farm, and therefore keep up the fertility and increase the manure heap. As the object of the fallow is to clean and enrich the land, it will be seen that its functions are in no way interfered with by the growth of roots. If root crops were sold (as occasionally they are), they would be even more exhausting to the land than the growth of corn crops. On the other hand, if grain is consumed (as it often is) upon the farm, as when beans or barley are ground up for stock, they may themselves be viewed as renovating crops.

Fodder crops are understood to be those crops grown for summer keep, and for the sake of leaves and stem, rather than for the root or grain. Such are vetches, rye, rye-grass, clover, sainfoin, lucerne, trifolium, trefoil, mustard, and rape. Some of them are sown upon the fallow section, and others are used to divide two corn crops, as when clover comes between barley and wheat in the Norfolk four-course rotation. Others again are mere "catch-crops" or stolen crops, as when mustard, rape, or even stubble turnips are taken after a wheat stubble, with the intention of providing extra keep in times of scarcity, or in the early spring. With respect to the first use of forage crops, they have been already recommended for clay lands. As to catch-cropping, or the taking of roots after vetches, trefoil, or trifolium, in the same season, we must remember that by so doing one great advantage of the fallowing season is lost, because the land is occupied with these two crops from autumn throughout the whole season. This seriously interferes with the proper cleaning of the land. It is a plan often resorted to in order to obtain sheep keep, but it should only be practised when the land is clean, and if continued it is apt to render it foul.

Theory of Rotations.

1. When we compare the composition of some of our ordinary crops with each other, we find that the proportions of ash ingredients and nitrogen differ widely. This

is in itself a key to one of the advantages of a rotation. If the same crop be grown year after year upon the same field, the soil is called upon to deliver up certain constituents in large quantities, while others are allowed to remain untouched. Turnips remove five times, beans three times, and oats twice as much potash from a soil as wheat. Oats require almost five times as much lime as wheat, and barley takes twenty-six times the amount of silica from the land as an equivalent crop of wheat.[1] Such illustrations might be multiplied, but the above examples sufficiently show that a succession of crops must be a relief to the drain upon certain constituents.

2. Plants search for their food differently. A plant which feeds in the upper layers of the soil, like peas or barley, is not likely to exhaust land for deeper-rooted crops, such as beans or red clover. The contrast between the root distribution of wheat and barley has been noticed by Mr Lawes and Dr Gilbert, who grew these two plants in pots. Only one fibre of barley found its way through the bottom of the pot, but "the wheat threw out such a mass of ramifications that the whole surface of the dish in which the pot rested was covered with a thick network of roots, as also was the bottom, and to a great extent the sides of the inside of the pot itself." The barley roots were congregated nearer the surface, and were more sparingly developed.

3. Certain plants or crops are especially fitted to precede others. Leguminous crops, as beans, peas, and clover are, for example, excellent precursors of wheat. The reason is that these plants leave a store of nitrogen available for the wheat crop, in the form of roots, and through the fall of the leaf during their growth. A good crop of clover assists in securing a good crop of wheat. Turnips and other root crops and potatoes are favourable

[1] The extraordinary amount of silica removed by barley is due to the adherence of its chaff to the grain. Wheat chaff is left on the farm.—J. W.

to the after-success of grain crops. Hence we shall find in most rotations that the succession of crops is determined by the nature of the preceding crop.

4. Certain crops seem to injure the soil for other crops. As might be expected, crops similar to each other do not succeed well in succession. Rye-grass is not a good preparation for wheat, and two white straw crops are not, as a rule, likely to succeed. Red clover refuses to grow after a previous crop or crops of the same plant, and it is well known that potatoes and turnips may be grown too frequently on the same field. This may be best explained upon the theory of rivalry for similar food constituents. De Candolle, the eminent French botanist, advanced the theory of root-excretions, to account for the difficulty of growing certain plants in succession, but the latest investigations upon this subject have yielded only negative results.

5. Besides the foregoing scientific reasons for varying the cropping of fields and following a well-devised rotation, there are several practical considerations which confirm their usefulness. (1.) They promote cleanliness or freedom from weeds; (2.) they give a continuous supply of food for stock, as well as grain for man; (3.) they divide the labour of the farm over the entire year; (4.) give a system to farming operations; (5.) and diminish a farmer's risks.

Abuses of Rotations.—They are, however, liable to abuse when unduly strained. No rotation can be suitable to all soils and to all conditions of the market, and therefore a degree of latitude should be allowed, especially upon large estates, where soils and climates vary.

Two White Straw Crops in Succession.—When a farmer has brought his land into high condition, it may be advisable to grow two white straw crops in succession. Upon his lighter lands he will probably take barley after wheat; upon his stronger lands he will take oats after wheat. By this system the best quality of barley is grown, and no harm can follow, provided a liberal system

is kept up. To rigorously forbid such cropping under all circumstances, is abusing the idea of rotations. Two white straw crops in succession is, however, only allowable when land is in high condition and clean.

CONTINUOUS CORN GROWING.—Of late years a good deal has been published in favour of continuous corn growing. It is proposed to grow corn consecutively upon the same field year after year, and to sell the entire produce both of corn and straw. Fertility is to be kept up by steam cultivation and the scientific use of purchased manures. The system is only proposed as applicable to clay land, which of all kinds is best adapted for the growth of corn.

That wheat and barley may be grown many years in succession upon the same land, no one can doubt. This has been proved by Mr Lawes, upon both kinds of grain. Wheat has now been grown thirty-three years in unbroken succession at Rothamsted, and on one portion without manure. It is true that when manure has never been applied, the yield has only averaged 13¾ bushels per acre over twenty-five years; and the average of the last ten years has been only 11⅞ bushels per acre. But where suitable manures have been liberally applied, there has been no difficulty in keeping up an average annual yield of 36 bushels per acre. Farmyard manure applied at the rate of 14 tons per acre per annum, has given an average yield of 34¾ bushels per acre. Mr Prout, of Sawbridgenorth, has been carrying out a system of consecutive corn growing for years, and Mr Middleditch, of Blunsdon, in Wilts, has been doing the same thing for a shorter period with success. There indeed seems to be no difficulty in growing many wheat or corn crops in succession, provided the fertility of the land is kept up by manure and good cultivation. There is no analogy between wheat and clover in this matter, for the wheat appears perfectly healthy and regularly grown over the entire surface after many previous crops, whereas red clover becomes liable to failure through clover-sickness.

How far this system is practicable it is difficult at present to form an opinion. Time may develop difficulties, but with the Rothamsted experience of thirty-three years before us, we need hardly fear any immediate check to a continuous succession of wheat crops. If adopted at all, it ought to be upon stiff clay land, and artificial manures should be liberally and judiciously applied.

If the system is in itself successful, it still remains a question whether it is wise. By growing corn after corn the same class and the same proportions of constituents are annually removed from the soil, and surely a root crop now and then, a crop of clover hay, or of potatoes, would be an improvement, since such crops would be likely to succeed, as a change. To banish live stock from the farm also is doubtful policy, and if these considerations are allowed fair play, we shall gradually see at least a partial return to the standard system of alternate forage and corn crops. The successful growth of wheat and barley at Rothamsted must, however, be regarded as an important fact bearing upon the future cultivation of certain classes of land.

ROTATIONS FOR STIFF SOILS.—The rotation followed must, in a great measure, depend upon the land. The great point is to grow suitable crops in a good order of succession. Upon stiff soils the bare fallow is restricted to wet or dirty pieces, which, having got out of order, require a summer's tillage. On the remaining portions the fallow will be sown or planted with suitable crops, as already indicated (p. 144). The fallow, whether bare or cropped, will on such soils be followed with wheat, as the most suitable and worthy crop to occupy such lands when at their maximum effectiveness. Grass seeds will be sown in the spring upon the young wheat, and occupy the land the third year; wheat may be taken again after seeds, beans after wheat, and wheat after beans, making a six-years' course, very suitable for a clay farm. The rotation would then be as follows:

Fallow (bare or cropped) : wheat : clover : wheat : beans : wheat.

The following rotation for stiff clays may be partially carried out in the south of England with good effect:

1st year.—Winter vetches fed off, and the land then broken up and sown with white turnips, rape, or even a second crop of vetches:
2d „ —Wheat, sown down in the spring (1.) with trefoil, (2.) mixed seeds, and (3.) a portion of the stubble sown down with trifolium (*T. incarnatium*):
3d „ —(1.) Trefoil portion mown and broken up for rape or turnips; (2.) portion left for pasture or mowing; (3.) portion mown for horses, and broken up for rape, turnips, etc.:
4th „ —Wheat:
5th „ —Winter beans, followed with winter vetches.

This is a modification of a rotation proposed by Mr Stace of Berwick, near Lewis, in Sussex, to enable clay-land farmers to compete with their brethren upon light land in the production of mutton and wool. It is commendable for the following good points:

1. It keeps three-fifths of the land in the most suitable corn crops for the class of land under consideration.

2. It involves working the land at the dryest, and therefore best, period of the year—the autumn.

3. It provides sheep keep during the summer, when no injury can accrue from the treading of sheep.

The objections to it are: That it throws more work into the autumn months than can be done without extra power, such as steam. And it is a rotation suitable only to clean land in the south of England. It would be apt to render land foul. In spite of these objections, the rotation is useful in principle, and might be carried out upon a small scale on many farms with advantage. For some other rotations, indicating the general course of cropping upon clay lands, see p. 143.

Rotations for Light Soils.—The "Four-course" or "Norfolk" system of cropping has been extensively

adopted upon a large proportion of light or free-working soils. It consists in taking successively—

Roots (usually fed on the land with sheep): barley: seeds: and wheat.

The excellence of this system lies in the equal division between grain and fodder, and it may in this sense be regarded as simply an alternation of these two classes of crops. The land is alternately manured and cropped with corn, and fertility is thus thoroughly kept up.

Neither is the system free from faults. It is too short, and if adhered to in the form above given, it yields but little variety. The many modifications adopted all tend to lengthen and vary the course, and make it suitable to many intermediate classes of soils.

MODIFICATIONS OF THE NORFOLK ROTATION.—According to the quality of the land and peculiarities of the climate, certain changes may be introduced into the Norfolk rotation, without disturbing the general principle of alternation which characterises it. The first important modification from the above-given four-course rotation is found in the introduction of winter vetches, rye, trifolium, or stubble turnips before roots. The rotation then becomes:

1st year.—Winter vetches sown in autumn and fed off in spring, the land being then prepared for roots:
2d ,, —Barley or oats
3d ,, —Clover:
4th ,, —Wheat.

This system of growing both a fodder and a root crop in one season has been commented upon already (p. 146), and may be said to be suitable for loamy, clean soils. It is not to be recommended in the north of England and Scotland, unless under exceptional circumstances, as the following considerations will show:

(1.) In the north the late harvest throws difficulties in the way of preparing stubbles for some of the above-named crops. (2.) The late spring prevents their early

maturation and use. (3.) Turnips and swedes being sown from a fortnight to a month earlier in the north than in the south, it often follows that the vetches are not cleared in time for a successful crop of roots. In spite of these difficulties, the plan of growing roots after vetches is occasionally followed even in Scotland.

When kept within due limits, the system of growing roots after forage crops answers very well in the Midlands and southern counties; but if pushed too far, it results in deficient root crops and foul land.

2. *Wheat may take the place of barley* on stiff soils, or *oats* may be substituted upon poor lands. The rotation will then assume the form of—

Roots, such as mangel, cabbages, and swedes (carried off): wheat or oats : seeds : wheat.

3. *Seeds may be left down two or three years.* This is an excellent method of lengthening the rotation into a five or six course:

Roots : barley or oats : seeds : seeds : wheat.

This plan is in favour in the west and north, but in the dry districts of the east of England one-year seeds is preferred.

Northumberland Rotation.—In Northumberland, Cumberland, and Durham, a five course of cropping is used. Seeds are allowed to lie two or three years, and are followed with oats instead of wheat, the wheat being taken after roots. It is somewhat singular that wheat does not succeed after lea in the northern counties. The course is as follows:

Roots : wheat : seeds : seeds : oats ; Or
Roots : wheat : seeds (lea) : seeds : seeds : oats.

There is a considerable saving in the labour bill by thus keeping two-fifths or one-half of the tillage land down in grass. Also, it is some advantage that the grass may be kept unbroken up until the end of December, when in-

tended to be followed with oats; whereas, when sown with wheat, as in the south, the grass or lea must be ploughed up in August or September, thereby sacrificing the autumn feed.

East Lothian Rotation.—In the neighbourhood of Dundee, and where the rich loams of the Old Red Sandstone encourage the cultivation of potatoes, the following rotation is in vogue:

Roots : barley (half dunged) : clover : oats (top dressed) : potatoes : wheat.

INFLUENCE OF SOIL IN DETERMINING ROTATIONS.—The general outline of a rotation may be thus drawn:

Fallow : grain : forage : grain.

The fallow may be naked or cropped, and the cropping of a fallow is capable of many modifications, according to the quality of the land. Similarly the grain crops and forage crops will be selected according to the capabilities and adaptabilities of the soil.

On the most retentive clays wheat and beans will be the predominating cereals, and bare fallows, relieved by the limited cultivation of rape, cabbages, kohl-rabi, kale, and vetches, will constitute the fallow portion.

On strong clay loams wheat and beans still hold their place, but the fallow will be cropped with mangels and swedes, in addition to the crops cultivated on the stiffer clays.

On loamy soils any crop is suitable—a fact which makes them particularly valuable. Potatoes may be mentioned as especially suitable for this class.

On sandy loams and sandy soils, white turnips are more suitable than swedes, forage crops are very successful, and these soils being easily worked are kept constantly under crop, and require the consolidating action of sheep during the winter. For such soils a system of catch-cropping is peculiarly suitable. Rye and barley will be found the most suitable cereals.

Calcareous soils are favourable to the development of those crops which require much lime. Among these may be mentioned the clovers, vetches, sainfoin, lucerne, peas, and beans. All these leguminous plants are in high favour in chalk and limestone districts.

Peaty soils will grow heavy crops of oats, and are well adapted for the growth of kohl-rabi and rape, while they are not suitable for swedes, turnips, or mangel.

Thin soils, with rock near the surface, although naturally poor, are capable of growing a capital quality of barley, and are suitable for the winter feeding of sheep by folding.

Deep soils will grow carrots well, and are good for almost any kind of crop.

All soils are to some degree capable of growing all crops. Therefore we shall find it advisable merely to modify a rotation according to the leading character of a soil, and by no means to adhere exclusively to the class of crops mentioned as peculiarly suitable.

PART IV.

LIVE STOCK.

Great Britain is rich in races of live stock. It boasts eighteen distinct breeds of cattle, at least twenty-five of sheep, and ten of swine; and each of these races has been improved by the breeder's art until British live stock is unrivalled throughout the world. English stock is eagerly purchased by foreigners and colonists, and this accounts for the extraordinary prices given for pure-bred animals. For the production of milk and beef English cattle excel all other races. It is true that we cannot compete with the flock-masters of southern Europe and Australia in the growth of fine wool. We do not attempt it, but restrict ourselves to the longer and coarser kinds, and the production of mutton, with most excellent results. No sheep in the world can touch our English Leicesters, Lincolns, or Cotswolds, for the combined production of wool and mutton.

It is not too much to say we have no such thing in the country as a fine woolled race. The last propagated was the Rylands of Herefordshire, but these have long been supplanted by Cotswolds and Shropshires. English swine are thoroughly appreciated on the Continent, and indeed it is extraordinary how familiar are the names of all our chief races of stock to Continental agriculturists.

RACES OF CATTLE.

SHORTHORNS (*Durhams*) are the most highly valued and extensively distributed of our races. They are now to be found throughout England, Scotland, Wales, and Ireland, and a large number are yearly exported to various parts of the world. The preference shown for shorthorns appears to be due to their combining a larger number of excellences than any other breed. They are good milkers, quick growers, rapid fatteners; docile, hardy, and pleasing in appearance. They may be described as red, white, red and white, and roan, in colour, well covered with long silky hair, licked in various directions, and of excellent symmetry.

Herefords are highly esteemed in the Midlands, and especially in their own county. In the production of beef they rival the shorthorn, but they are poor milkers. The Hereford is red in colour, with white face, mane, ridge of back, tip of tail, breast, belly, and feet. In form he is massive and square in front, but his prominent buttocks and narrowness at the hocks give him a rather plain appearance behind.

Devons are chiefly confined to their own county. They may be described as a small but beautifully-formed race, excellent feeders, capital workers when yoked, but poor milkers. The colour is a fine deep red, unbroken at any part save on the udder or scrotum, according to sex. The horns are fine, nicely curved, and coloured yellow at the base. The muzzle, eyelids, and insides of the ears are also of rich yellow colour, which lightens up the countenance.

Sussex cattle are in many points similar to the last race. They are larger in carcase, and duskier in the features, but in colour and configuration there is a close general resemblance. Probably both of these races are direct descendants of the original cattle of the country, such as are still to be seen in Chillingham and Chartley parks. The breeders of Sussex cattle are justly proud of them, and

consider that they are possessed of a race which is rapidly rising in public estimation.

Norfolk Polls constitute another red but hornless race, inhabiting Norfolk and Suffolk. Like almost all races of cattle, it has met with zealous supporters and friends, among whom Lord Sondes may be mentioned. It now boasts its herd-book.

Suffolk Duns, an excellent race of milking cattle, somewhat resembling the last, and supposed to have resulted from crossing Galloway heifers, imported from Scotland for grazing purposes, with the cattle of the district.

Longhorns.—This race is interesting as having been the earliest improved breed. It was bred with great care by Robert Bakewell in the middle of the last century, and became widely distributed and much appreciated. The shorthorn and other races, however, superseded it, and it is now in few hands. Its peculiarities are exceedingly long horns, sweeping downwards and curving, in many cases, under the jaw, brindled sides, pied back, and great length of carcase. It is still seen in Warwickshire and adjacent counties.

Galloway cattle, the first Scotch race to be noticed, occupy the south-western peninsula of Galloway, and Wigton. They are a black polled (hornless) race, well covered with hair, thick fleshed, hardy, and much esteemed by English graziers. Large droves are yearly sent across the border, and distributed among the turnip-growers and graziers of the north and east.

Angus cattle occupy the north-eastern portion of Scotland, especially in Aberdeen. They are like the last, a black and polled race, larger and looser in frame, and shorter in the hair than the Galloway.

Ayrshire cattle constitute one of the best of our dairy races, highly esteemed in the manufacture of Ayrshire or Dunlop cheese. In colour it is red and white, but is often nearly white, and sometimes exhibits the dusky or smoked and shaded colours seen in the Channel Island cattle. The form indicates milking properties by the

lightness of the fore quarters and heaviness of the hind quarters. They are said by judges to be "*wedge-shaped*," by which is meant, that they are narrow in front and gradually thicken backwards, and this configuration is noticeable alike when viewing them broadside and from above.

West Highland cattle are found purest in the Hebrides, where they met with an energetic improver in Mr M'Neil. They now occupy the Highlands of Scotland from east to west, and are thoroughly well adapted for their position. They are brown, black, brindled, silver-grey, and mouse grey, covered with a thick and long coat, decorated with long, upright, white horns; they are of medium or somewhat low stature, and very beautifully proportioned.

Among the chief Welsh breeds may be mentioned the black *Pembrokes*, white only on the udder or scrotum, and furnished with long white horns. The *Castle Martins* are another black race, and the *Glamorgans* have been much crossed with the Hereford race.

Channel Island Races.—These are popularly known as "Alderneys," but more strictly are described as Jersey and Guernsey cattle. Both are essentially milking races, and possess the peculiar configuration which usually accompanies this aptitude. Like the Ayrshire race, they are light in front and heavier behind, are somewhat bony, with clean deer-like cheeks and muzzle, lively ears, and large open eye. The hair is short and sleek, giving them rather the appearance of Swiss cows. *Jersey* cattle are silver-grey, fawn, or "smoke" coloured, finely shaded on the neck, flank, and haunches, in many cases almost to blackness. The nose is black, with light hair around. At the Royal Agricultural Shows at Taunton (1875) and Birmingham (1876), a considerable latitude evidently, in the matter of colour, was allowed, as Colonel Barrows' first prize bull was reddish yellow, with somewhat darker neck and haunches. The *Guernsey* cattle are generally fawn and white, occurring in irregular patches, and have white noses.

COMPARATIVE MERITS OF DIFFERENT RACES.—From the above brief notice it will be seen that the various breeds of cattle are suitable for different localities and purposes. Each of them has numerous admirers, and to advocate the claims of one over another is apt to arouse a storm of disputation. Under these circumstances, it is difficult to speak of any one race as the best for any particular purpose, but we may safely allow the claims of each in its own locality. No doubt peculiarities of soil, herbage, and climate, peculiarly fit the West Highlander for the Highlands, and the Shorthorn for the Lowlands; the Devon for the mild and humid air of their own country; and the Sussex and Norfolk for the drier air of the east and south-east counties. Of all races, the Shorthorn has shown the greatest powers of adaptation to different soils and situations, and we are only following the bent of agricultural opinion throughout the country if we allow that this race is of all others the most valuable. There are, however, exceptional conditions in which other races may be kept with greater advantage.

For grazing purposes, Shorthorns, Herefords, Sussex, Devons, Galloways, Angus, and West Highlanders, are all largely used.

For dairying, Shorthorns, Ayrshires, and Irish Kerry cows, are in high repute.

For private families, Jerseys, Guernseys, Ayrshire, and Kerry cows are great favourites.

For work, the Devon steer is allowed to be best, but Herefords, Sussex, and even Shorthorns, are also employed in the few localities where oxen are used for purposes of draught.

In selecting the best kind of stock for any particular farm, judgment is required not only in fixing upon the race most suitable, but also the age and condition of the cattle selected. The accomplished grazier readily detects the capabilities of a farm for particular purposes.

The best quality of grass is devoted to "finishing" large steers already brought into forward condition. Six

or eight weeks upon first-rate grazing land not only increases their actual weight, but improves the value per stone, and transfers them from second quality into the class of prime beef.

Land of lower quality will graze or fatten small steers or heifers, or may be stocked with dairy cows.

Much second-rate grass is devoted to cheese-making and the growth of young stock.

High-lying moors and rough pastures constitute our chief rearing districts, and supply well-grown young steers to the holders of richer lands. The close proximity to a town or railway station often develops a profitable new milk trade.

On arable land bullocks usually occupy the stiffer class of farms, the lighter lands being, wherever practicable, under sheep.

It is highly important that stock should be transferred to better keep, and not to worse. Hence, in purchasing stock, the farmer should endeavour to select animals from a less favourable soil and local climate than his own.

Such are the chief points of difference to be taken into account in determining the selection of stock, and from their number it is evident that serious mistakes may be made by the inexperienced.

Management of Cattle.

Wherever possible, it is advisable to breed a sufficient number of calves to keep the farm supplied with stock. When this is not practicable, some calves may be purchased to make up the requisite number. By this policy two important points are gained. First, the profits of both breeder and grazier are pocketed; and as of late years lean stock have been so dear as to seriously lessen the profits of graziers, this is an important consideration. Wherever the farm is extensive, and comprises land of various quality, from good

to bad, this system will be found by far the most profitable. Secondly, it is safer, for owing to the great traffic in cattle from foreign countries, horned stock is liable to a number of serious ailments, and these are contracted by contagion and infection in the market. The less therefore that the farmer needs to go into the market to buy cattle the better.

Calves.—The period of gestation in the cow is usually 285 days. If parturition takes place before this period, the probability is that a female calf will be born, if after, the chances are in favour of a bull calf. The most suitable time for a calf to be born is from the middle of March to the middle of April. Calves are either brought up by hand or allowed to suck their dams. The first plan is best when they have subsequently to run on comparatively poor land until they are old enough to fatten. The second plan may be adopted in the case of high-bred stock, or where it is intended to fatten the animals at an early age. The first plan entails a new milk diet; the second allows of old milk and artificially-made gruels being introduced, and is therefore cheaper. If the natural system of suckling is adopted, the cow and calf are left together in a roomy box. If the artificial plan of bringing up by hand is followed, the calf is at once removed to a suitable sparred hutch or crib, 4 feet long, 4 feet broad, and with partitional rails or spars 4 feet high. A series of such hutches are conveniently arranged in an airy, light, and dry building, called the calf-house. Here the calf is laid upon a bed of dry straw, and thoroughly wisped or rubbed until dry. It receives about a pint of the first milk (*colostrum*) or "beistyn," which is of thicker consistency than ordinary milk, and of slightly aperient property. This no doubt assists to remove the contents (*meconium*) of the lower intestines which have been accumulating during the later fœtal life. The first day a calf will require feeding every four or five hours, and subsequently it will be fed three times daily until the end of the first week.

and twice afterwards. The following amounts will be sufficient:

2d	day, 1 quart morning.	1 quart noon.	1½ quarts night.
3d	,, 1½ ,,	1½ ,,	2 ,,
4th	,, 2 ,,	1 ,,	2 ,,
5th	,, 2 ,,	1 ,,	2 ,,
6th	,, 2½ ,,	1 ,,	2½ ,,
7th	,, 2½ ,,	1 ,,	2½ ,,
8th	,, 3 ,,	0 ,,	3 ,,
9th	,, 3 ,,	0 ,,	3 ,,
10th	,, to end of first month, 4 quarts morning.	0 ,,	4 ,,
Second month,	4 ,, (old milk).	0 ,,	4 ,, (old milk).
Third month,	4 ,, (old milk).	0 ,,	4 ,, (old milk).

At twelve weeks old a calf may be weaned.

Mr Bowick of Bedford,[1] for many years manager to Mr Howard of Biddenham, Beds, gives the following amounts of milk as requisite for a young calf:

> 1st week, with the dam, or 4 quarts per day, at two meals.
> 2d and 3d weeks, 5 to 6 quarts per day, at two meals.
> 4th and 5th ,, 6 ,, 7 ,, ,,

and the quantity need not ever exceed a couple of gallons per day.

Mr Bowick also found that a cow may be made to suckle five calves in the year, by first giving her two, and when these are weaned, two more; and when her milk lessens in quantity, one will be sufficient. This would occupy her nine months.

Mr H. Ruck, a tenant on Lord St German's Gloucestershire estates, described an excellent system of bringing up calves with little or no milk. He purchased calves from dairymen at ten days old, and gradually altered their milk diet to one of gruel. The gruel consisted of:

[1] Prize Essay on the Rearing of Calves, by Thomas Bowick (Dayson & Hewitt, London, 1865), and Journal of R.A.S., vol. xxii., part i., 1861.

7 lbs. of finely-ground linseed-cake.
7 ,, mixed ,, meals.
2 gallons of hay tea.
4 ,, warm water.

This is given night and morning, after further diluting, as follows: 2 quarts of the gruel, mixed with 2 quarts of water, in the morning, and the same at night. This system is capable of many modifications, but requires constant attention to render it successful.

During summer calves will run in a paddock or close near the buildings, and should have the shelter of a shed to protect them from the heat. In October, or when the nights become cold and grass deficient, they will be brought into a roomy, well bedded, comfortable fold-yard, provided with a shed, and there they will receive pulped roots, and 1 to 2 lbs. of crushed barley, cake, or meal, according to the state of the markets. They may be placed near the work-horse stable, or cow or fatting stalls, and will then pick over any litter and waste food thrown out from these offices, and assist to tread down and improve the manure. Young stock also suffer less from the passing to and fro, inseparable from stables and cow houses; and the more retired folds will be occupied by fatting cattle.

Yearlings.—Cattle retain the name of calves until they have completed their first year, and are called yearlings until they are two-year-old, and "two-year-olds" until they are three, etc. The winter management of calves becomes the management of *yearlings* as soon as the calf has completed its first year. It is continued with but little alteration until the grazing season arrives, when the young stock are turned out to grass, and in many cases they receive no extra indulgence beyond what they can find for themselves. With fair pasturage, and plenty of water, young cattle will "do" well, and require but little supervision. The chief point is to adapt the description of stock to the class of land available for their use. By November they will be brought home

to the buildings, and hardy animals may be allowed to roam even later. The management of young stock during the second winter is usually a simple matter. As in the first winter, the degree of indulgence must be in accordance with their future prospects. Young stock which are intended to run out on grass of middling quality for a third summer ought not to be highly fed, while in other cases it may be desirable to push them forward in order to make them into beef. As an excellent plan, capable of adaptation to store stock of all ages, that carried out and described by Mr Coleman of Park Nook, is worthy of notice:

"His stock consisted of one, two, and three-year-olds in about the same proportion, and were, on the whole, well bred. Hay and straw in the proportion of 1 to 4 were chaffed together, and given to grown animals at the rate of 2½ bushels per head per day, together with half a bushel of pulped roots, and 2 lbs. of linseed-cake, or an equivalent of some other cake or meal. The plan of proceeding was as follows: A cemented cistern, something like a small grain pit, 5 feet deep, is sunk 2½ feet into the ground. A layer of chaff, 6 inches deep, is spread over the bottom, and upon this is laid a thin stratum of pulped roots in the proportion of 1 bushel of roots to 4 bushels of chaff. Meanwhile, a soup of finely ground linseed-cake and water, in the proportion of 1 lb. of cake to a gallon of water, has been boiling, and 4 or 6 gallons of it are now poured hot over the pulped roots and chaff in the cistern, stirring the whole mass together and stamping it down. This process is repeated until the cistern is completely full. After twenty-four hours the flavour of the cake and roots will so permeate the chaff that the whole forms a savoury and palatable food. Mr Coleman frequently wintered his stock without any hay, and in this practice he agrees with many of our best farmers, who are beginning to think hay an expensive luxury for horned stock" (*Agricultural Gazette*, November 28, 1874).

Two-year-olds.—Before winter is over the young cattle will have completed their second year, and will be spoken of as "two-year-olds." As the season advances they will in ordinary practice once more go out to grass, and towards the middle or end of October they will come into the buildings to be fatted off. Previous to this they should have received turnips on the pastures to accustom

them to winter fare. It is a golden rule, applicable alike to all classes of stock, to avoid rapid changes of diet. Sudden changes of food are a fertile source of colic and inflammation in the stable, of blackquarter or inflammatory fever in the cattle-yards, and of sudden death in the sheep-fold. The quality and quantity of food should be always increased with judgment; and the changes of the season, necessitating as they do a complete change of diet, are times of peculiar watchfulness to owners of stock.

Fatting Cattle.—At two and a half years old cattle are most usually put up to feed, and in fifteen to twenty weeks, or towards the completion of their third year, they are sold to the butcher. Before the times of Bakewell and the brothers Colling, it was rare for a bullock to be fatted before he reached the mature age of five. But, owing to careful selection of parents, the time has been, in even the most ordinary cases, reduced by two years. In Northumberland it is now customary to bring cattle out fat at twenty-two months old, and "two-year-old beef" is now by no means uncommonly brought into market. The more ordinary course is, as already stated, to complete the fattening process a little under three years old. The system pursued varies to a great degree with the supply of roots. In the north, where roots are both more abundant and of better quality, and where the straw also appears to be more nutritive, turnips and straw constitute the basis, and oil-cake or meal given in increased quantities, from 3 to 6 or 8 lbs. per diem, comprises the entire system.

In the southern counties, a more elaborate system of feeding is practised, in which roots occupy a subordinate position, and greater attention is paid to the allowance of dry food. Up to the present time hay has also been largely used in cattle feeding; but owing to its high price, and the greater range of feeding stuffs now available, less is used than formerly. The weight of roots (turnips) which a full-grown ox will consume in one day is very large. Mr Cowie found a pair of working oxen consumed 500

lbs. of turnips daily, and the writer has found even two-year-old cattle to eat 168 lbs. each. In modern feeding, with a view to fattening, these quantities have been reduced in some cases down to 20 lbs., but more ordinarily to from 50 to 60 lbs. daily, the remainder of the necessary bulk of food being given in the form of cut straw, meal, cake, and water. It is indeed possible to feed cattle profitably without roots, as is practised on certain clay farms when the character of the land is unfavourable to their growth. The following system of feeding has, with slight modifications, been carried out for many years upon the Royal Agricultural College farm, Cirencester. The cattle are accommodated in boxes (10 feet by 11 feet), and receive 20 lbs. to 30 lbs. of roots daily, with cut straw (chop), and a liberal allowance of barley-meal and cake. The quantity of cake and meal is gradually increased from 3, 4, and 5 lbs. daily at the commencement of the period, to 9 and 10 lbs. at the later stages. The times and method of feeding are as follows:

At 5.30 to 6.0 A.M., meal mixed with chaff, and just enough pulped roots to moisten the chaff.
,, 7.30 to 8.0 A.M., 20 lbs. of sliced roots.
,, 9.30 A.M., meal and chaff as before.
,, 12.0 P.M., oil-cake and chaff.
,, 2.0 ,, meal and cake as before.
,, 4.30 ,, meal and cake as before.
,, 6.0 ,, 4 to 6 lbs. of hay.

Water is constantly before the animals.

SHEEP.

RACES OF SHEEP.—The British races of sheep are classified according to the length of their wool, into *long*, *short*, and *middle* woolled breeds. Long and short woolled sheep differ in several other respects from each other than in the length of their wool:

Long-woolled sheep yield a heavy fleece, are heavier in weight, yield a somewhat coarse mutton, deposit fat thickly on the back, have white faces and legs, are well adapted for low-lying and rich lands, require plenty of room.

Short-woolled sheep yield a lighter fleece, are lighter in weight, supply mutton of high quality. Their fat and lean are better mixed, and they lay on much inside fat. The faces and legs are usually brown. They are naturally fitted for high-lying downs, and are constantly associated with the chalk hills. Will bear confinement in folds.

Under the general term of long-woolled sheep will be included the Leicester, Cotswold, Lincoln, Bampton, and Romney Marsh breeds; and among the chief short-woolled races may be mentioned Sussex or South Downs, Hampshire Downs, Oxford Downs (a crossed race), Shropshires (a mixed race), Dorset-horns, Kentish Downs, Norfolk and Suffolk Downs, and Cheviots.

Besides the above highly cultivated races of sheep, which, together with their crosses, occupy almost the whole of the agricultural land of England, there are a large number of mountain and forest races. Such are the sheep of Dartmoor and Exmoor, the Morfe sheep of the Longmynde, the Heath or Blackfaced breed of the north, the Lonks, and the Crag or Limestone sheep of West Yorkshire and East Lancashire, the Herdwicks of Cumberland and Westmoreland, the Welsh mountain sheep, etc.

The British Isles boast at least twenty-five distinct breeds of sheep, all of considerable interest. It would, however, take us beyond our limits to attempt to describe them. The work has been well done by the late Professor Low of Edinburgh in his exhaustive treatise, "The Domesticated Animals of the British Islands" (Longman, London), a work which should be studied by every agricultural student. The *Journal of the Royal Agricultural Society* contains valuable essays upon the various breeds of sheep, among which, that of Mr R. Smith, vol. viii., Mr T. Rowlandson, vol. x., and Professor Wilson, vol. xvi., all of the first series, will be found highly interesting.

Sheep are the most important live stock upon our mountains, moors, and fells, and upon all the lighter, drier, and thinner soils under arable cultivation. The richer pastures and clayey arable lands are stocked to a greater degree with cattle; but wherever the land is dry and light enough to be benefited by the treading of sheep during the winter, sheep will always prevail. The reason of this is economy, for it is much less expensive to consume turnips upon the land where they grew, by means of sheep, than to cart them to a distance for cattle. The labour of bringing back the manure from the cattle lairs is also very considerable, so that it is scarcely too much to say that £1 per acre is saved when the nature of the land will allow of winter folding. Sheep are also very independent, require no buildings, and do not need such constant attention as cattle. Wherever sheep can be kept, they therefore will take the precedence of cattle as a profitable stock, and especially so on those light sandy soils, which positively require the consolidating effects of the treading of sheep to enable them to produce a corn crop.

Sheep thrive all the better for having plenty of room and plenty of change, both of ground and food. These peculiarities, taken in connection with what has already been advanced, point out chalk downs and oolitic hills, as exemplified in the English downs, the Cotswolds, and the Lincolnshire heath, as well adapted for sheep. They form high-lying tracts of thin, dry, and light textured soils, giving a firm footing throughout winter, and are well adapted for producing the root and forage crops suitable for sheep. These are therefore among our chief sheep districts. The characteristics of sheep land are still more strongly brought into view by contrasting it with the sort of locality in which cattle are preferred. The great dairy and grazing districts of England lie upon the Lias clay in Somersetshire, Gloucestershire, Derbyshire, and Leicestershire, and upon the clay marls of the New Red Sandstone of Cheshire. The Weald of

Sussex, the marshes of Lincolnshire, the strong lands of Essex, Huntingdon, Bedford, Staffordshire, and many other localities, are stocked chiefly with cattle. The sheep, in a word, is for the hills, and the ox for the plains.

Management of Sheep.

Sheep may be bred, reared, and fattened upon the same farm. Such is the ordinary practice upon the chief sheep districts of England, and it may be recommended as the most profitable sort of management wherever the land is moderately fertile and of dry character. In the north of England and Scotland the labour of rearing and fattening is often divided, the breeding being confined to the hills, and the lambs being sold into the hands of the lowland turnip-growers towards winter.

The Ewe Flock.—Ewes bring their first lamb at two years old, and continue, as a rule, three and a half years in the flock. They produce during this period three "crops" of lambs, and are drafted or culled at four and a half years old. By this system the ewe flock is kept young, and at its maximum value. Age is, however, not the only reason for drafting. A defective ewe may be culled sooner, and a particularly good one retained longer in the flock. Each ewe should be examined annually before she is used for breeding purposes, with a view to the following points: (1.) A defective udder, caused often by inflammation and supperation; (2.) State of the teeth; (3.) General soundness and freedom, or the reverse, from rupture; (4.) Faults of fleece, form, or character. A ewe may be condemned for defectiveness under any of these heads, as well as on account of age.

The management of a ewe flock may be said to commence immediately after the season's lambs have been weaned, and if we follow their treatment up to the corresponding period of the succeeding year, we shall have a fair idea of the course generally pursued.

When weaning time arrives, which will usually be to-

wards the end of May, the ewes are removed to dry and short pasturage for two reasons: (1.) to dry up their milk; (2.) on the score of economy. During the next few weeks they are kept upon seeds, or run behind fatting sheep folded on vetches, eating up what is left for them. In July they are employed to eat down lea-land grass intended to be broken up for wheat, and act as scavengers, eating what sheep destined for the fat market have left behind them. After the middle of August they are treated more liberally, in order to bring them into good condition before the rams are turned out, and in September they often receive a "tie" or fold of rape or mustard as a change from seeds or permanent pasture.

Rams are turned out at various times. In Dorset, Hamps, and the Isle of Wight, where Dorset horned ewes are kept to supply early lamb to the London market, the ewes receive the ram as early as April. Ram breeders and those who raise fat lambs always turn out their rams earlier than those flock-masters who only aim at producing mutton. In the south of England August may be considered early. Many farmers consider the third week in September a suitable time, and as the period of gestation in ewes is twenty-one weeks or thereabouts, this brings the commencement of the lambing or yeaning season to about the 7th to 10th of February. Further north, October is preferred, and on the hills of Cumberland, Lammermuir, and the Scotch Highlands, the season is postponed until late into November. In accordance with these seasons the lambs will come either in the bitter month of February, when they require a great amount of superintendence; in the boisterous month of March, when early green keep, in the shape of rye and rye-grass, is on the eve of appearing; or in April, when there is an abundant supply of spring keep.

Rams are turned out in the proportion of one to sixty ewes, a greater or less number being apportioned to each male according to the character of the ground, and according to numerous other considerations. Where extra care

is taken in improving a flock, a greater number of rams will be employed, each being mated with those ewes which his peculiar excellences are thought likely to correct. On fertile and enclosed land, where the ewes do not wander, fewer rams are needed than on bare hill-sides, where the flock is scattered over a wide extent of country.

Ewes ought to be in good condition when with the ram, as they are then more likely to conceive and to produce "double couples." At the end of six or seven weeks the rams are removed, and the ewes are then once more run on poor keep, such as stubbles, old seeds, and permanent pasture. The season will by this time have advanced to the beginning of November, and winter may be expected to set in at any time. Ewes are too frequently mismanaged during winter. They are allowed to remain too long in one place; they are left upon low-lying damp situations; they are subsequently folded upon turnips, with most disastrous results. A better plan is to proceed up to the time the rams are turned out as already indicated. When the wet weather sets in in November, they should be removed to a dry high-lying lair, which has been kept uneaten for the express use of the ewe flock at this season. There they will do well, and should the weather be hard or the pasture bare, a single horse cart-load of cabbages or turnips may be given among 200 ewes daily. A little chop, or hay and straw cut up short with the chaff-cutter, will be also well bestowed, and towards lambing time a quarter-pound of oats or cake may be given. By this management the flock is kept healthy; they are never crammed with an excessive quantity of cold roots, often at a temperature below the freezing-point of water; and they do not slip about upon a muddy fold, which must often be injurious to pregnant animals. Ewes are thus tided over January, and by that time they should be brought each night into the lambing pen.

THE LAMBING SEASON.—A lambing pen should always be provided. It is most conveniently constructed of high

hurdles, thatched and placed so as to form a roomy enclosure of square or oval shape.

Fig. 13 will give some idea as to the general plan of a lambing pen. It is divided into three or four parts by lines of hurdles, and a straw stack, A, gives shelter, and supplies litter for keeping the enclosure comfortable. The large court, B, will be, during the early period of yeaning, devoted to unlambed ewes, which will have free ingress and egress through the openings C, C. Parts D and E will be occupied by ewes and lambs, the one by the younger and the other by older lambs. The double couples may also

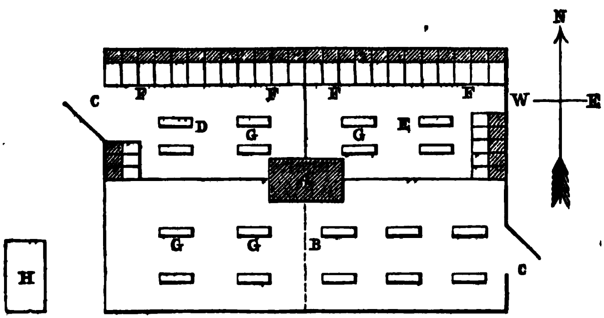

Fig. 13.—Plan of Lambing Pen.

A, straw stack; B, court for unlambed ewes; C, C, gates for passing out to turnip-fold; D, division for older lambs; E, division for younger lambs; F, F, pens for newly-yeaned lambs; G, G, racks for hay; H, shepherd's temporary house on wheels.

be kept separate from the single lambs. F, F, F, represent a series of small pens, made by placing hurdles at right angles to the inner side of the enclosure. Thus a number of hutches or cells are formed, and each is partially roofed by hurdles laid along the tops and covered with straw. A hurdle in front completes the arrangement, and each cell will thus form an independent little yard and shed for the accommodation of newly-lambed ewes. G, G, are racks or

troughs for hay. The pen is erected in close proximity to the supply of food. White or yellow turnips are preferred for this purpose.

Ewes which may be expected to lamb within a fortnight are first brought down to the pen, and the later ewes follow as the older lambs begin to be drafted off to distant fields, and thus the lambing pen is never crowded. When a ewe shows symptoms of approaching parturition she is carefully watched, but must not be interfered with, as in most cases she gives birth to her offspring without assistance. Should the presentation be abnormal, the shepherd extracts the lamb, and as soon as this is effected lamb and dam are placed in a cell or hutch, and the ewe is supplied with a little hay and a turnip or two.

The management of newly-lambed ewes is perfectly simple when, as is nearly always the case, the lamb is born naturally, and without any untoward circumstance. She is fed on usual diet, and after three days she is considered to be out of danger. Lambs are very hardy when they are well supplied with milk, and after a week or fortnight of shelter in and about the pen they may be sent, with their mothers, to a distance. During the lambing season the shepherd is in constant attendance day and night, and sleeps in the wooden house H. The points requiring his attention are numerous, and the student should endeavour to participate in his cares if he really means to master the subject. The author perfectly concurs with that distrust of "book-learning" so often expressed by practical men, when it is unsupported by practical experience. General principles, and even minute directions, can be obtained from books, but their value is only realised by the student who observes and practises in the field. Among the difficulties which a shepherd has to deal with are the various forms of false or unnatural presentations of the fœtus; ailments of the ewes both before and after lambing; ailments of young lambs; deficient supply of natural food; ill-temper and positive repugnance on the part of the mother to her offspring;

the fostering of orphans upon mothers who have lost their own lambs; the preservation of comfort and cleanliness in the pen, not by any means easy in wet weather; and the general care of ewes and lambs in all stages, so that all are content, and the lambs are kept progressing.

Lambs, when only a few days old, begin to nibble at the turnip leaves; or, if placed on seeds or pastures, to feed upon the grasses and clovers. Considering that good sheep-farming entails the production of a fat "teg," fit for the butcher at ten months old, weighing from 76 to 80 lbs. of marketable mutton, every day becomes of importance. According to this estimate, a lamb must increase at about the rate of a quarter of a pound every day from birth, and as injudicious or careless feeding may involve a loss of weight, always difficult to make up again, it is evident that constant progress is to be aimed at. At a fortnight old, lambs should have a little finely-ground linseed-cake, bruised oats, and bran, mixed together, and placed in troughs outside the fold. Lamb-hurdles should be provided, not only to give them egress to the troughs, but that they may run forward to pick the tenderest turnip tops or the freshest blades of grass, while the mothers follow upon what must be somewhat staler fare.

As the season progresses, the "couples," as ewes and lambs are called, leave turnips and turnip-greens for rye, vetches, water-meadow, seeds, pasture, or whatever other green food is available. Folding the ewes and allowing the lambs to run before receiving extra indulgence in the shape of about 2 oz. of mixed cake and corn is good management, but some farmers prefer their couples to wander over the fields without the restraint of hurdles. Preference is given to "double couples" in the matter of keep. We are thus brought once more to weaning-time, which usually takes place when lambs are ten to twelve weeks old. It will have been noticed that the ewe flock is sometimes kept rather short, and at other times more liberally. The entire year may indeed be divided into

four parts, two of which are periods of liberal, and two of poor keep. From weaning to the middle of August they are on meagre fare, from mid-August to the time the rams are removed they are on better pasture; during November, December, and January they are kept in good health, but, on the whole, economically; and finally, from before yeaning up to weaning-time they fare well, with their lambs.

TREATMENT OF LAMBS.—During the first few weeks of a lamb's life its well-being, to a great extent, depends upon its mother. Therefore ewes should be fed well, and a little corn and cake should not be grudged, especially for those which have double couples to support. The general management of lambs up to weaning has been already noticed, and we now pass on to the summer management of lambs. The following rules will, if observed, ensure well-grown hoggets: (1.) Frequent change of pasture; (2.) The continuance of dry food in the form of bran, bruised oats, and oil-cake; (3.) Access to water; (4.) Access to rock salt; (5.) Constant supervision; (6.) In hot weather, and if folded, sheep should be provided with shelter in the shape of thatched hurdles, supported horizontally upon stakes, about six feet from the ground, in order to protect them from the sun. This precaution is more requisite for heavy sheep, such as rams or show stock, than for lambs. There is a saying in Lincolnshire that grass should be twenty-four hours old for a sheep, and eight days old for a bullock. It is thought advisable by many shepherds to change their lambs to new pastures daily; and certainly no greater mistake can be made than that of keeping them long in one place. Mr W. J. Edmonds, in addressing the Cirencester Chamber of Agriculture on the important subject of sheep-feeding, spoke as follows: "We must bear in mind that if, by care and good living, we can, humanly speaking, make ten or eleven stone weight each of our young sheep some time in January, that is, at from ten to eleven months old—sheep full of flesh and good quality—we can keep

a heavier breeding flock, and by that means make more mutton, and also grow more wool than we could if, by less liberal living, we were unable to dispose of them before March or April, or, as is the case in many instances, even later. Now, how are we to attain so desirable an end? I believe in this way, by not only preventing our lambs from losing flesh, but by doing our utmost to make them gain flesh from the very moment they leave their mothers. There is ordinarily not much danger of their losing condition before, because nature supplies the food most suitable to their wants. Still, even for two or three weeks before they are weaned, I would recommend a small quantity of pea-meal or oil-cake dust to be given, just to use them to it; then as soon as they are weaned, which with me is generally done while folding on seeds, two ounces of cake or split peas each (I prefer oil-cake) from that time until August, their other food consisting of grass, vetches, and latter-math clover—two kinds of food are best—then rape and vetches, or rape, until the time comes for them to be cautiously put on to turnips. Towards the end of August, or even before, unless the weather is very hot, I would add to the other food a quarter of a pound of cracked beans each, and as the season advanced, increase by degrees the oil-cake until it reached three quarters of a pound each (if straw chaff be given), but if a fair proportion of good hay, I think half a pound would be ample. By such living, sheep may be brought to good weights, fat, yet with plenty of flesh, at eleven, if not at ten months old, without forcing so as to produce disease, and without extravagant living."

Winter Treatment of Hoggets.—When lambs go on to turnips they are generally spoken of as hoggets or tegs. The change from summer to winter keep should be made as gradually as possible. As green food begins to fail, a fold of rape or a few cabbages spread over the pastures will prepare the sheep for the introduction of white turnips. When they are accustomed to the tur-

nips, they may be gradually brought into confinement in the turnip-fold. It is, or was, the custom in the north to starve the hoggets into eating turnips by confining them between nets, and not allowing them any other food. Such a system is opposed to sound principles and to good practice, as is proved by the fact that lambs so treated are expected to lose ground for at least a few days after being placed on turnips.

The allowance of cake may be increased to a quarter of a pound daily, and should be mixed with chopped hay and straw mixed. Cracked beans and peas may also be mixed with the cake with great advantage. Not only does the addition of dry food help to grow and fatten the tegs, but it prevents diarrhœa. White turnips are more suitable than swedes during September, October, and the first half of November. Afterwards swedes may be gradually substituted, and the change may be made still more gentle by giving yellow turnips with white, then yellow alone, and afterwards yellow turnips and swedes, before they are put on pure swedes. This is to avoid the evil of sudden changes of diet. By Christmas the amount of cake and corn will have been increased up to half a pound daily, and after that period it may be further augmented until it reaches a maximum of one pound per head per day by 1st February. It is also usual to give an allowance of long hay in racks as well as chop, mixed with dry food. A good system of feeding is to give a feed of cake, corn, and chaff at seven A.M., cut roots at nine, cut roots again at eleven, a feed of cake, corn, and chaff at noon, cut roots at three, and the rack filled with hay towards dark. By this system the heat of the body is kept up, and the cold roots are counteracted by the drier and more concentrated foods. It has been proposed to pulp roots for sheep in the field, but as yet the plan has not been adopted on a large scale.

It will be found economical to grind turnips for fatting tegs from the first, but ewe hoggets, intended to be kept for breeding purposes, and therefore kept upon less

forcing food, may break their own turnips, eating them off the ground just where they grew.

The following rules may serve as guides for the winter management of fatting sheep: (1.) The feeding must be regular and progressive; (2.) Dry food must be liberally supplied; (3.) The troughs and racks must be kept clean and sweet; (4.) The fold must be regularly shifted over the land, to secure equal distribution of manure; (5.) In continued wet weather, it may be advisable to remove sheep on to grass land, and then supply them with food until the land is dry enough to support them.

THE FATTENING PROCESS.

1. FOOD.

The rearing and fattening of stock are the highest developments of agriculture. The conversion of the mineral matter of the soil and the treasures of the air into saleable crops is the first step. The conversion of vegetable matter into flesh is the final process, after which flesh is returned again to the domain of earth and air.

The same substances employed in the organisation of vegetable matter are required in the animal body. Thus we find all the mineral substances of the soil, together with nitrogen, in animal matter. Certain organic substances elaborated during the life of plants, such as vegetable albumen, caseine, and fibrine, fats and oils, starch, sugar, etc., are readily assimilated in the animal body; and corresponding compounds, known as animal albumen, caseine, fibrine, and fat appear. Hence the connection between the composition of the animal and the plant are just as intimate and vital as that between the plant and the soil.

Before proceeding with the subject of fattening cattle, it is necessary to notice the chief substances in the food supplied, from which cattle, sheep, and pigs derive their increase.

These have been divided into the following groups:

(1.) WATER; (2.) ASH; (3.) AMYLOIDS or CELLULOSE GROUP; (4.) the PECTOSE GROUP; (5.) FATS and OILS; (6.) the ALBUMINOID or PROTEINE BODIES.

WATER is present in every food. In so-called dry foods it occurs in the proportion of 14 per cent., as in the cereal grains, or 15 to 17 per cent., as in ordinary hay. In fresh fodder and roots it is by far the most abundant material present, as the following figures will show. The quantity varies with the stage of growth and other circumstances.

Grass, . .	70 to 80 per cent.	Mangel leaves, .	90 per cent.
Red clover, .	78 to 83 ,,	Turnip leaves, . .	88 ,,
Sainfoin, .	80 ,,	Turnips, ...	92 ,,
Vetches, .	82 ,,	Swede turnips, .	91 ,,
Rape, . .	87 ,,	Mangel, ...	88 ,,
Cabbage, .	84 to 89 ,,	Potatoes, . . .	75 ,,

Store cattle, sheep, and pigs, contain water in the proportion of from 60 to 63 per cent. of their entire live weight.[1] Water may therefore be viewed as a permanent constituent of the animal body. It is also the vehicle by which the various substances used in nutrition are carried to their destination in the body, or brought back for elimination after they have performed their part.

Foods deprived of a considerable portion of their water, as hay, for example, do not suffer in other respects, and water is sufficiently abundant in this country to enable the stock-feeder to supply it separately. While allowing the immense importance of water, we cannot ascribe a value to it in a commercial sense.

ASH.—The ash of plants is important as furnishing material for building up bone, and supplying the salts which are ever present in blood and animal tissues.

AMYLOIDS OR CELLULOSE GROUP.—This group comprises *cellulose, starch, inuline, dextrine, gum,* the various

[1] See Lawes on "The Composition of Oxen, Sheep, and Pigs, and their Increase while Fattening," vol. xxi., series i., p. 433, *Journal of the Royal Agricultural Society.*

kinds of *sugar*, etc. They are all composed of carbon, hydrogen, and oxygen, in many cases combined in the same proportion by weight. The composition of the chief members of the group is as follows:

Cellulose,	$C_6H_{10}O_5$.	Cane sugar,	$C_{12}H_{22}O_{11}$.
Starch,		Fruit sugar,	$C_6H_{12}O_6$.
Inuline,		Grape sugar,	
Dextrine,			
Bassorine,			
Veg. mucilage,			

Cellulose is the outer coating or wall of the vegetable cell, and since every agricultural plant is composed entirely of cells, cellulose forms a large proportion of every vegetable substance. The fibres of cotton, hemp, and flax (linen), and the "skeletons" of leaves, are good examples of pure cellulose. It is insoluble in water, alcohol, ether, and the oils, but is converted into dextrine, and finally into sugar, when kept in prolonged contact with strong sulphuric acid. When old, it is digested with difficulty by animals, but as it occurs in the young stems and leaves of forage plants, it is readily appropriated in the digestive process, and ranks as a nutritive substance.

Starch occurs in the cells of the cereal grains, of the tubers of the potato, and of the tubers and pith of arrowroot and sago palm, etc. Wheat contains 60 per cent. of starch, and barley, owing to its adhering chaff scales reducing the percentage amount, only 38·5 per cent. Although insoluble in water, it is readily converted into *dextrine* (British gum) when exposed for some hours to a moderate heat. Dextrine is readily soluble in water. The saliva of man and herbiverous animals also dissolves starch at blood heat, by converting it into sugar. It is still more quickly converted into sugar by the liquids of the large and small intestines,[1] and hence it is one of the most valuable forms of food.

Starch, dextrine, gum, and sugar are all valuable ingredients of food. Their non-nitrogenous nature unfits them

[1] "How Crops Grow."

from repairing the waste of muscle, while the prevalence of carbon and hydrogen point them out as sources of heat and force in the animal body. They are, therefore, above other food constituents, styled heat-producers and respiratory compounds.

The PECTOSE GROUP includes *pectose*, *pectin*, *pectic* and *metapectic* acids, all of which are derived from fleshy fruits. Pectin also occurs in melons, marrows, turnips, beet, cabbage, etc. Pectose is a somewhat apocryphal substance which has never been separated from its combinations, but is considered, for theoretic purposes, to exist in unripe fruit, and to be the source of pectin. In the process of ripening pectose softens, becomes soluble in water, and changes into pectin. The same changes occur when apples, pears, or turnips are baked or boiled. If the clarified juice of ripe fruit is treated with its own bulk of alcohol, the pectin is precipitated as a stringy, gelatinous mass. Pectosic, pectic, and metapectic acids are formed from pectin under the influences of fermentation and a regulated temperature, and they differ from each other but slightly in composition. The chemical formula of pectin is $C_{32}H_{48}O_{32}$.

FATS AND OILS.—The fattening properties of fats and oils are thoroughly well known. All the most ordinary fats, whether occurring in the animal or vegetable, are composed of *stearine*, *palmitine*, and *oleine*. They contain three-fourths of their weight of carbon, and the remaining weight is formed of hydrogen and oxygen. Fat or oil, when taken into the animal system, is quickly converted into animal fat, as is illustrated by the fattening effects of foods in which it abounds.

It has been shown that the nutrient power of starch and sugar is much inferior to that of fat or oil. Mr Lawes, writing upon this subject, expresses himself as follows: "Of the non-nitrogenous constituents of food, starch and sugar have, weight for weight, nearly equal feeding values; malt sugar has probably rather a lower value than either cane sugar or starch; digestible cellulose, in moderate

proportion, has for ruminant animals probably nearly the same value as starch; and fat or oil has probably about two and a half times the value of starch for the purposes of respiration, or the storing up of fat in the body."

THE ALBUMINOIDS differ from the amyloids and fats in containing, besides carbon, hydrogen, and oxygen, about 15 to 18 per cent. of nitrogen, with a small quantity of sulphur, and in some cases phosphorus. The chief members of this group, albumen, caseine, and fibrine, have been already named. Their composition, whether occurring in vegetables or animals, is almost identical, and may therefore be typically represented by that of animal albumen (the characteristic ingredient of white of egg), which is as follows:

Carbon, ...	53·5 per cent.
Hydrogen, ...	7·0 ,,
Nitrogen, ...	15·5 ,,
Oxygen, ...	22·4 ,,
Sulphur, ...	1·6 ,,

In blood fibrine and glutine of wheat, the proportion of nitrogen rises to 17·4 and 18·1 per cent., while the carbon and oxygen are correspondingly reduced. The albuminoids are called proteine compounds, from their physiological importance. In the animal organism the albuminoids of the food are dissolved in the gastric juice of the stomach, and ultimately pass into the blood, when they form blood albumen and blood fibrine. As the blood nourishes the muscles, they are modified into flesh fibrine, or, entering into the lacteal system, are converted into caseine, while, in the appropriative parts of the circulation, they are formed into albumen.[1] Recent investigations have tended to show that the proteine compounds are capable of being so decomposed in the process of digestion as to yield fat, together with highly nitrogenous products, which may be employed in or expelled from the system.

[1] "How Crops Grow."

Albuminoids should form a considerable proportion of all food. Some substances are exceedingly rich in them, as, for example, beans, peas, and lentils, which contain them in the proportion of 22 to 24 per cent. of their entire weight.

In other foods, as maize and barley, the albuminoids constitute only 10 per cent. of the entire seed. The question at once arises, what is the right proportion in which the albuminoids or nitrogenous constituents of food should be blended with the non-nitrogenous or amylaceous elements? The answer to such a question, supplied by Mr Lawes, was as follows: "If I were asked to state in general terms what was the approximate proportion of the nitrogenous to the digestible non-nitrogenous substances, below which they should not exist in the food of our stock, I should say (though with reservations), about such as we find them in the cereal grains."[1]

From the foregoing remarks, it will be seen that all the valuable food constituents may be classified as non-nitrogenous and nitrogenous. The former class includes the cellulose, pectose, and fatty groups, or all those which are composed of carbon, hydrogen, and oxygen—hence called carbo-hydrates. The latter class comprises the albuminoids.

It would be unwise to attribute a higher importance to either one or the other of these classes. Both are essential to the development of the animal body. In the fattening process, however, we must give the preference to the non-nitrogenous constituents, and especially to the vegetable fats and oils, as chief sources of fat, and because the fattening of cattle really means the accumulation of fat in the body.

In the feeding of stock the farmer has two objects in view; first, the production of meat; but also, and scarcely less important, the making of manure. Now, while allowing that the digestible carbo-hydrates are most important nutrients, there is no doubt at all that the nitro-

[1] Mr Lawes on the Feeding of Animals (Dublin), March 1864.

genous food constituents must be relied upon to enrich the manure-heap. This fact is well illustrated in the table (p. 107), in which the theoretical value of the manure produced by the consumption of one ton of various foods is given. Reference to the table will show that the manure produced from nitrogenous foods, such as oil-cakes, beans, and lentils, is very superior in value to that resulting from the consumption of maize and barley.

In the Appendix will be found a table of foods, translated from Dr Emil Wolff's excellent little book, "*Die rationelle fütterung der landwirthschaftlichen Autzthiere*" (1874). The percentage of water, ash, organic matter, crude proteine, crude fibre, extractive matter free from nitrogen, and fat, in each food, is given. The next three columns comprise the entire nutritive matter under the three heads, albumen, digestible carbo-hydrates, and fat. Still further to the left is a column showing the relation of albuminoids to digestible carbo-hydrates in every food. Thus, opposite wheat we read 5·6 in this column, which means that, as 1 : 5·6, so is the ratio between the albuminoids and carbo-hydrates in wheat—*i.e.*, it is $\frac{1}{5\cdot 6}$ of the whole. The calculation is made as follows: The fat is multiplied by 2·5 to reduce it to its equivalent in starch or sugar. This in the case of wheat equals $1\cdot 2 \times 2\cdot 5 = 3$. This is added to the remaining carbo-hydrates, and the quotient is divided by the proportion of albuminoids. Thus

$$\frac{63\cdot 1 + 3}{11\cdot 7} = \text{ratio of albuminoids to total carbo-hydrates}$$
$$= 5\cdot 65 \text{ or } \frac{1}{5\cdot 6} \text{ of the whole grain.}$$

Mr Lawes' opinion has already been quoted to show that the proportion of albuminoids to carbo-hydrates is most perfectly adjusted in the cereal grains, of which wheat may be taken as the type. The extreme variation from this standard in many foods is easily seen in the table under consideration. Thus, in peas, it rises to 1 in 2·7, and in maize it falls to 1 in 8·3; in wheat straw it falls to

1 in 41·1, and in bean straw it rises to 1 in 7·3. One of the richest foods in albuminoids (curious to us from its novelty) is cockchafers, which have been recently employed in Germany for cattle feeding. Dried cockchafers contain 38·0 per cent. of albuminoids, no digestible amyloids, and 9·1 of fat; and this fat, calculated into the starch equivalent, gives the ratio of albuminoids to carbohydrates as 1 : ·6, or above ten times the proportion existing in wheat. Dried cockchafers then might be used in small quantities to bring up the proportion of albuminoids in amylaceous foods, and, indeed, the object of this column of the table is to assist the stock feeder to select his foods in accordance with the ratio between these two most important classes of food constituents.

The next column embodies an attempt to value foods. The figures are not strictly applicable to English money, but are obtained by a somewhat elaborate calculation, based upon German weights and coinage. The relative value is, however, preserved. The values are obtained by estimating the chief ingredients at the following scale:

Albuminoids,	24
Amyloids,	4
Fats,	10

The last column gives the relative value of the various foods when compared with a standard. All hay, green fodder, straw, chaff, and husk are compared with average meadow-hay, which is taken at 1. All roots, tubers, grain, seeds, and waste products are compared with the grain of rye as 1. Rye would scarcely be adopted in England as a standard, because it is rarely grown, except for fodder. But since wheat, compared with rye as a food, has only a value (according to these estimates) of 1·07, it may be used almost equally well as the standard of comparison. Dr Wolff's estimate of the comparative feeding value of some of our most important foods will be found to be as follows:

Rye,	1·00	Beans,	1·45
Wheat,	1·07	Linseed-cake,	1·52
Barley,	0·86	Rape-cake,	1·42
Oats,	0·84	Cotton-cake (undecorticated),	1·07
		,, (decorticated),	1·68

2. Feeding and Fattening.

Having briefly considered the composition of food, the next subject is that of feeding. The ordinary methods, involving the frequency of meals and the quantities of food usually given per diem, have already occupied us. It remains for us to consider the process of fattening, with the changes in the animal body that it involves. For the following facts and figures I am in a great measure indebted to the laborious and expensive investigations of Mr Lawes of Rothamsted, Herts, and his indefatigable colleague, Dr Gilbert, who together well deserve the title of England's greatest agricultural chemists. The student who wishes to study the subject of fattening stock, should certainly study Mr Lawes' many valuable contributions on the subject to the *Journal of the Royal Agricultural Society*.

Rapid growth and the accumulation of fat are opposed to each other. Consequently, animals fatten most rapidly when they have acquired their full stature. Since, however, bullocks will grow until they are six years old, and are generally turned into beef before they are three, sheep before they are more than a year old, and pigs at nine to twelve months, it is evident that growth and fattening must proceed simultaneously in the case of most of the animals fatted in this country. This is a point of some importance, since it teaches us that the requirements of a young animal put up to fatten are not limited to fat-forming materials, but involve a plentiful supply of flesh-forming and bone-forming substances.

When tegs are sold as fat at ten months old to the butcher, they must have been fatted from birth. In this brief period the entire mass of muscle (lean), as well as

fat, has been composed; and it seems, therefore, scarcely correct in speaking of teg-feeding to hold that the fattening process merely consists in the accumulation of fat. In the case of a lean ewe, or a lean six-year-old bullock, we might so speak, and the feeding might be regulated according to such ideas; but in the manufacture of ten-month-old mutton and two-year-old beef the production of flesh, fat, and bone go on simultaneously, and must be provided for by suitable foods. Growing animals will require a larger share of albuminoids; and it has been shown that as they approach maturity they are more inclined to select foods of a non-nitrogenous character.

Our knowledge of the precise functions performed by the constituents of food must still be regarded as unsettled. The terms *fat formers*, *heat producers*, and *force producers* were, until very recently, indiscriminately applied to the carbo-hydrates, starch, sugar, and fat. Recently the views of many leading physiologists have been altered, and, while fats and oils are still regarded as producers of fat, starch and sugar are looked upon more exclusively as maintainers of the animal heat and producers of vital force. This view, it will be observed, does not detract from the nutrient value of these substances, because animal heat and force would, but for their presence, require to be supplied from the fats and albuminoids of the food. The albuminoids have also recently been regarded as probable sources of fat. They, like the carbo-hydrates, contain the elements of fat in the form of carbon, hydrogen, and oxygen, and, by their decomposition in the animal system, they may become sources of fat, as well as of highly nitrogenised products available for other purposes.

The following table of Dr Wolff's fully illustrates the last remark. It shows the amount of each of the principal food constituents required by different animals at different stages of growth, as well as during the fattening process.

Tables showing the Amount of the Chief Food Ingredients consumed by Animals at various Stages of Growth and in various Conditions.

(A) Per 1000 lbs. of Live Weight per Day.

Kind of Animal.	Total Dry Organic Substance.	Albuminoids.	Amyloids.	Fat.	Ratio of Albuminoids to Carbohydrates.
	lbs.	lbs.	lbs.	lbs.	
Oxen in complete rest, . .	17·5	0·7	8·0	0·15	1:12·0
,, moderately worked, .	24·0	1·6	11·3	0·30	1:7·5
,, hard worked, . . .	26·0	2·4	13·2	0·50	1:6·0
Oxen fattening, 1st period,	27·0	2·5	15·0	0·50	1:6·5
,, 2d ,,	26·0	3·0	14·8	0·70	1:5·5
,, 3d ,,	25·0	2·7	14·8	0·60	1:6·0
Sheep fattening, 1st period,	26·0	3·0	15·2	0·50	1:5·5
,, 2d ,,	25·0	3·5	14·4	0·60	1:4·5
Swine fattening, 1st period,	36·0	5·0	27·5		1:5·5
,, 2d ,,	31·0	4·0	24·0		1:6·0
,, 3d ,,	23·5	2·7	17·5		1:6·5
Growing cattle:					
Age in months. Live weight.					
2—3 150 lbs.	22·0	4·0	13·8	2·0	1:4·7
3—6 300 ,,	23·4	3·2	13·5	1·0	1:5·0
6—12 500 ,,	24·0	2·5	13·5	0·6	1:6·0
12—18 700 ,,	24·0	2·0	13·0	0·4	1:7·0
18—24 850 ,,	24·0	1·6	12·0	0·3	1:8·0
Growing sheep:					
Age in months. Live weight.					
5—6 56 lbs.	28·0	3·2	15·6	0·8	1:5·5
6—8 67 ,,	25·0	2·7	13·3	0·6	1:5·5
8—11 75 ,,	23·0	2·1	11·4	0·5	1:6·0
11—15 82 ,,	22·5	1·7	10·9	0·4	1:7·0
15—20 85 ,,	22·0	1·4	10·4	0·3	1:8·0
Growing swine:					
Age in months. Live weight.					
2—3 50 lbs.	42·0	7·5	30·0		1:4·0
3—5 100 ,,	34·0	5·0	25·0		1:5·0
5—6 125 ,,	31·5	4·3	23·7		1:5·5
6—8 170 ,,	27·0	3·4	20·4		1:6·0
8—12 250 ,,	21·0	2·5	16·2		1:6·5

(B) Per Head per Day.

Kind of Animal.		Total Dry Organic Substance.	Albuminoids.	Carbo-hydrates.	Fat.	Ratio of Albuminoids to Carbo-hydrates.
Growing cattle:		lbs.	lbs.	lbs.	lbs.	
Age in months.	Live weight.					
2—3	150 lbs.	3·3	0·6	2·1	0·30	1:4·7
3—6	300 ,,	7·0	1·0	4·1	0·30	1:5·0
6—12	500 ,,	12·0	1·3	6·8	0·30	1:6·0
12—18	700 ,,	16·8	1·4	9·1	0·28	1:7·0
18—24	850 ,,	20·4	1·4	10·3	0·26	1:8·0
Growing sheep:						
Age in months.	Live weight.					
5—6	56 lbs.	1·6	0·18	0·87	0·045	1:5·5
6—8	67 ,,	1·7	0·17	0·85	0·040	1:5·5
8—11	75 ,,	1·7	0·16	0·85	0·037	1:6·0
11—15	82 ,,	1·8	0·14	0·89	0·032	1:7·0
15—20	85 ,,	1·9	0·12	0·88	0·025	1:8·0
Growing swine:						
Age in months.	Live weight.					
2—3	50 lbs.	2·1	0·38	1·50		1:4·0
3—5	100 ,,	3·4	0·50	2·50		1:5·0
5—6	125 ,,	3·9	0·54	2·96		1:5·5
6—8	170 ,,	4·6	0·58	3·47		1:6·0
8—12	250 ,,	5·2	0·62	4·05		1:6·5

The first table is based upon the amount of each class of food constituent required per day per 1000 lbs. of live animal, and the second (B) shows the amount consumed per head per day. It is striking to notice the high percentage of albuminoids consumed by young cattle, and to contrast it with the much smaller proportion required by mature oxen during the period of rest. Also it will be noticed that oxen at hard work, and during the fattening period, require the same proportion of albuminoids in their food as is furnished in wheat.

Table B. being calculated on the per head per day basis,

gives a new series of figures, which, however, bear out the decreasing proportion in which albuminoids are required.

If we restrict ourselves more exclusively to the subject of fattening more or less mature animals for the butcher, the process may be described as the storage of fat in the body. No doubt, to some extent, flesh or muscle is increased, and the younger the animal the more may this be expected to take place. The percentage of nitrogenous substances will be found to decrease in comparison with the non-nitrogenous or fatty substances. This has been shown by Mr Lawes, who has spared no expense in ascertaining the average composition of oxen, sheep, and pigs:

TABLE.—COMPOSITION PER CENT. OF OXEN, SHEEP, AND PIGS, IN THE STORE AND IN THE FAT CONDITION.

	OXEN.		SHEEP.		PIGS.	
	Store.	Fat.	Store.	Fat.	Store.	Fat.
Nitrogenous substance, . . .	18·0	15·0	15·0	12·5	14·0	10·5
Non-nitrogenous substance (fat),	16·0	30·0	18·0	33·0	22·0	44·0
Mineral matter, . .	5·2	4·0	3·5	3·0	2·8	1·8
Total dry substance,	39·2	49·0	36·5	48·5	38·8	56·3
Water, ...	60·8	51·0	63·5	51·5	61·2	43·7
Total, . .	100·0	100·0	100·0	100·0	100·0	100·0

In all the above cases fattening appears to consist in doubling the original proportion of fat, and diminishing the percentage of water, ash, and nitrogenous substances.

OXEN, SHEEP, AND PIGS COMPARED AS MEAT PRODUCERS.—The comparative merits of oxen, sheep, and pigs, as producers of meat, must depend to a considerable extent upon the range of prices in the market, both with regard to lean stock, the flesh produced, and the food required to make it. It is therefore impossible to form an opinion as to which may, at any particular period, be the

most profitable to keep. We may, however, compare them with reference to the foods most suitable for them, and the use they make of the food supplied.

The three animals are very different from each other, but sheep and oxen, as ruminants, have much in common. The digestive system, and the organs which compose it, must be of primary importance in studying this part of our subject. Consequently we find, both in England and Germany, tables have been constructed showing the proportional weight of the various parts of the body. I select the following, prepared by Mr Lawes, as convenient, and as bearing directly on the point before us:

TABLE SHOWING THE RELATION OF PARTS IN ANIMALS OF DIFFERENT DESCRIPTIONS AND IN DIFFERENT CONDITIONS OF MATURITY.

	In Different Animals.			In Sheep in different Conditions.		
Average of	Oxen. 16	Sheep. 249	Pigs. 49	Store. 5	Fat. 100.	Very Fat. 45.
Stomachs and contents, ...	11·6	7·5	1·3	9·1	7·0	5·6
Intestines and contents, ...	2·7	3·6	6·2	5·3	3·8	2·8
	14·3	11·1	7·5	14·4	10·8	8·4
Internal loose fat, .	4·6	6·9	1·6	4·5	6·0	7·5
Heart, aorta, lungs, windpipe, liver, gall-bladder and contents, pancreas, spleen, and blood, ...	7·0	7·3	6·6	8·4	7·7	6·5
Other offal parts, .	13·0	15·0	1·0	17·9	16·1	13·1
	38·9	40·3	16·7	45·2	40·6	35·5
Carcase, ...	59·3	59·2	82·6	53·4	58·7	64·1
Loss by evaporation, etc., . . .	1·8	0·5	0·7	1·4	0·7	0·4
	100·0	100·0	100·0	100·0	100·0	100·0

The first striking fact is the extraordinary difference in proportional weight of stomach between cattle, sheep, and pigs, and, conversely, it will be seen that as the stomach with its contents diminishes, the intestines increase in relative weight. Adding stomach and intestines together, the ox is seen to possess a larger share of them than sheep, and sheep than pigs. The ox, indeed, has twice the weight of stomach and intestines (with contents) than the pig. Oxen are thus seen to be better adapted than the sheep, and still more so than pigs, for bulky food. They require more woody fibre or cellulose, and a less concentrated diet. Sheep require richer food than oxen, but the pig has not the necessary apparatus for dealing with large masses of crude vegetable fibre. Hence, additions of bran, or other bulky and innutritious matter, to the food of pigs is never advisable, and they do best on the meal of cereal grains, such as barley.

Relations of Food to Increase.—Once more we must have recourse to the results obtained by Mr Lawes and Dr Gilbert. The accompanying table, showing the conclusions arrived at, after numerous experiments on a large scale, as to the quantities of hay, cake, and swedes necessary to produce 100 lbs. of increase in live weight, is in itself an interesting and valuable result. It appears that in the case of oxen 250 lbs. of oil-cake, 600 lbs. of clover-chaff, and 3500 lbs. of swedes are required for this purpose; and in the case of sheep, 250 lbs. of oil-cake, 300 lbs. of clover-hay, and 4000 lbs. of swedes will suffice. The character of the food consumed by both species of stock is very similar, but the total dry matter and indigestible fibre is greater in the case of cattle.

Turning to pigs, we find 500 lbs. of barley-meal producing 100 lbs. of increase in live weight. The increase is composed more exclusively of fat and less of nitrogenous (lean) substance than in the case of either sheep or oxen. The large proportion exhaled by pigs from their lungs and skin is also remarkable, and considerably exceeds the loss through the same channels in the other animals. That

the pig stores up a much larger proportion of his food than oxen or sheep is only to be expected from the concentrated character of his diet. Reference to the section of the table showing the amounts of increase from 100 parts of dry substance of food supplied, shows this clearly, the pig storing up 17·6 per cent., the sheep 8 per cent., and the ox only 6·2 per cent. of the total dry matter contained in the food. It is hardly necessary to repeat that this increase is chiefly fat, derived chiefly from the consumption of the non-nitrogenous elements of food. Whether also derived from the decomposition within the system of albuminoids, does not indeed affect the fact that, while the system retains non-nitrogenous materials in comparatively large quantities during the fattening process, the nitrogenous elements are mostly returned as excrementitious matter to the dung-heap.

TABLE BY MR LAWES, SHOWING FOOD, INCREASE, MANURE, ETC., OF FATTENING ANIMALS.

OXEN.

	250 lbs. oil-cake, 600 lbs. clover-hay, 8500 lbs. swedes, and Supply— Produce 100 lbs. Increase,				100 lbs. Total Dry Substance of Food Supply—			Amount of each constituent of Food stored up for 100 lbs. of it consumed.
	In Food.	In 100 lbs. Increase.	In Manure.	To Respiration, etc.	In Increase.	In Manure.	To Respiration, etc.	
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Nitrogenous substance,	218	9·0	323	636	0·8	29·1	57·3	4·1
Non-nitrogenous substance,	818	58·0			5·2			7·2
Mineral matter,	83	1·6	81	...	0·2	7·4	...	1·9
Total dry substance,	1109	68·6	404	636	6·2	36·5	57·3	

SHEEP.

	250 lbs. oil-cake, 300 lbs. clover-chaff, 4000 lbs. swedes, Produce 100 lbs. Increase, and Supply—				100 lbs. Total Dry Substance of Food Supply—			Amount of each constituent of Food stored up for 100 lbs. of it consumed.
	In Food.	In 100 lbs. Increase.	In Manure.	To Respiration, etc.	In Increase.	In Manure.	To Respiration, etc.	
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Nitrogenous substance,	177	7·5	229	548·5	0·8	25·1	60·1	4·2
Non-nitrogenous substance, . .	671	63·0			7·0			9·4
Mineral matter,	64	2·0	62	...	0·2	6·8	...	3·1
Total dry substance,	912	72·5	291	548·5	8·0	31·9	60·1	

PIGS.

	500 lbs. barley-meal produce 100 lbs. Increase, and Supply—				100 lbs. Total Dry Substance of Food Supply—			Amount of each constituent of Food stored up for 100 lbs. of it consumed.
	In Food.	In 100 lbs. Increase.	In Manure.	To Respiration, etc.	In Increase.	In Manure.	To Respiration, etc.	
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Nitrogenous substance,	52	7·0	59·8	276·2	1.7	14·3	65·7	13·5
Non-nitrogenous substance, . .	357	66·0			15.7			18·5
Mineral matter,	11	·0·8	10·2	...	0·2	2·4	...	7·3
Total dry substance,	420	73·8	70·0	276·2	17·6	16·7	65·7	

APPENDIX.—TABLE SHOWING THE AVERAGE COMPOSITION OF VARIOUS KINDS OF FOOD, AND THE COMPARATIVE VALUE OF EACH.

Description of Food.	Quality and Condition when cut.	Water.	Ash.	Organic matter.	Albuminoids.	Crude fibre.	Extractive matter, free from Nitrogen.	Fat, etc.	Nourishing Constituents.			Ratio of Albuminoids to Carbo-hydrates.	Comparative value.	
									Albumen.	Carbo-hydrates.	Fat.		Value of food in shillings per cwt.	Meadow hay as standard.
I. HAY.												As 1:		Hay =1.
Meadow hay,	Poor.	14·3	5·0	80·7	7·5	33·5	38·2	1·5	3·4	34·9	0·5	10·6	2·27	0·75
”	Better.	14·3	5·4	80·3	9·2	29·2	39·7	2·0	4·6	36·4	0·6	8·2	2·62	0·86
”	Middling.	14·3	6·2	79·5	9·7	26·3	41·6	2·3	5·4	41·1	0·9	7·9	3·03	1·00
”	Good.	15·0	7·0	78·0	11·7	21·9	42·3	2·2	7·4	42·1	1·0	6·0	3·56	1·17
”	Very prime.	16·0	7·7	76·3	13·5	19·3	40·8	2·6	9·2	43·1	1·2	5·0	4·07	1·34
Red clover,	Poor.	15·0	5·1	79·9	11·1	28·9	37·7	2·1	5·7	37·9	1·0	7·1	2·99	0·99
”	Middling.	16·0	5·3	78·7	12·3	26·0	38·2	2·2	7·0	38·1	1·2	5·9	3·32	1·10
”	Good.	16·5	6·0	77·5	13·5	24·0	37·1	2·9	8·5	38·2	1·7	5·0	3·74	1·23
”	Very prime.	16·5	7·0	76·5	15·3	22·2	35·8	3·2	10·7	37·6	2·1	4·0	4·28	1·41
White clover,	Middling.	16·5	6·0	77·5	14·5	25·6	33·9	3·5	8·1	35·9	2·0	5·0	3·58	1·18
Lucerne,	”	16·0	6·2	77·8	14·4	33·0	27·9	2·5	9·4	28·3	1·0	3·3	3·49	1·15
”	Good.	16·5	6·8	76·7	16·0	26·6	31·8	2·3	12·3	31·4	0·9	2·7	4·29	1·42
Sainfoin,	In flower.	16·7	6·2	77·1	13·3	27·1	34·2	2·5	7·6	35·8	1·4	5·2	3·39	1·12
Alsike clover,	Middling.	16·0	6·0	78·0	15·0	27·0	32·7	3·3	8·6	34·8	1·8	4·6	3·63	1·20
Yellow clover (trefoil),	...	16·7	6·0	77·3	14·6	26·2	33·2	3·3	9·2	36·4	2·0	4·5	3·87	1·28

Bokhara clover,	...	14·3	8·0	77·7	16·7	30·3	27·9	2·8	8·5	31·7	1·6	4·2	3·47	1·15
Crimson clover,	...	16·7	5·1	78·2	12·2	30·4	32·6	3·0	6·2	34·9	1·4	6·2	3·03	1·00
Serradella (*O. sativus*),	In flower.	16·7	7·5	75·8	13·5	22·0	35·6	4·7	8·5	36·2	2·8	5·1	3·77	1·24
Vetches,	,,	16·7	8·3	75·0	14·2	25·5	32·8	2·5	9·4	32·5	1·5	3·9	3·71	1·22
,,	Before flowering.	16·7	9·3	74·0	19·8	23·4	28·5	2·3	15·1	31·1	1·4	2·3	5·00	1·65
Vetch and oat-hay,	...	16·7	7·2	76·1	12·6	28·0	33·2	2·3	7·2	35·9	1·1	5·4	3·28	1·08
Peas,	In flower.	16·7	7·0	76·3	14·3	25·2	34·2	2·6	9·4	33·1	1·6	4·0	3·74	1·23
Lupines,	After flowering.	15·0	6·3	78·7	11·8	30·5	33·5	2·9	7·8	38·4	0·9	5·2	3·50	1·16
,,	When flowering	16·7	4·1	79·2	23·2	25·2	28·8	2·0	17·2	36·0	0·6	2·2	5·65	1·86
Field spurry,	...	16·7	9·5	73·8	12·0	22·0	36·6	3·2	7·6	36·8	1·9	5·5	3·48	1·15
Green rye-hay,	...	14·3	5·1	80·6	10·4	23·1	44·5	2·8	6·6	44·3	1·3	7·2	3·48	1·15
Timothy grass,	When flowering.	14·3	4·5	81·2	9·7	22·7	45·8	3·0	5·8	43·4	1·4	8·1	3·27	1·08
Italian rye-grass,	,,	14·3	7·8	77·9	11·2	22·9	40·6	3·2	7·1	41·5	1·4	6·3	3·50	1·16
Perennial rye-grass,	,,	14·3	6·5	79·2	10·2	30·2	36·1	2·7	5·1	35·3	0·8	7·3	2·71	0·89
French rye-grass,	...	14·3	9·9	75·8	11·1	29·4	32·6	2·7	5·6	33·1	0·8	6·3	2·74	0·90
	...	14·3	5·8	79·9	9·5	28·7	39·1	2·6	5·3	40·9	1·1	8·2	3·02	1·00
Mohar (millet) hay (*Panicum Germanicum*),	...	13·4	5·7	80·9	10·8	29·4	38·5	2·2	6·1	41·0	0·9	7·1	3·19	1·05
Tree leaves,	End of July.	16·0	7·0	77·0	10·5	14·2	49·3	3·0	7·4	46·2	1·4	7·0	3·77	1·24
	...	11·4	14·0	74·6	18·3	10·6	38·0	7·7	12·8	36·0	4·9	3·8	5·00	1·65
II. GREEN FODDER.														
Grass,	Just bef. flowering	75·0	2·1	22·9	3·0	6·0	13·1	0·8	2·0	13·0	0·4	7·0	1·04	0·34
Pasture grass,	...	80·0	2·0	18·0	3·5	4·5	9·2	0·8	2·4	9·9	0·4	4·5	1·02	0·34
Rich pasture grass,	...	78·2	2·2	19·6	4·4	4·8	9·6	0·8	3·1	10·8	0·4	3·8	1·22	0·41
Italian rye-grass,	...	73·4	2·8	23·8	3·6	7·1	12·1	1·0	2·3	12·6	0·4	5·9	1·09	0·36
Perennial rye-grass,	...	70·0	2·0	28·0	3·6	10·6	12·8	1·0	1·8	12·2	0·3	7·2	0·35	0·31
Timothy grass,	...	70·0	2·2	27·8	3·4	8·0	16·3	1·1	2·1	16·0	0·5	8·2	1·19	0·39
	...	70·0	2·1	27·9	3·4	10·1	13·4	1·0	1·9	14·2	0·5	8·1	1·08	0·36
Green rye,	...	76·0	1·6	22·4	3·3	7·9	10·4	0·8	1·9	11·0	0·4	6·3	0·94	0·31
Green oats,	...	81·0	1·4	17·6	2·3	6·5	8·3	0·5	1·3	8·9	0·2	7·2	0·69	0·23
Mixed oats and vetches,	...	84·0	1·4	14·6	2·4	5·4	6·4	0·4	1·4	6·9	0·2	5·4	0·61	0·20

TABLE SHOWING THE AVERAGE COMPOSITION OF VARIOUS KINDS OF FOOD, AND THE COMPARATIVE VALUE OF EACH—*Continued.*

DESCRIPTION OF FOOD.	Quality and Condition when cut.	Water.	Ash.	Organic matter.	Albuminoids.	Crude fibre.	Extractive matter, free from Nitrogen.	Fat, etc.	Nourishing Constituents.			Ratio of Albuminoids to Carbo-hydrates.	Comparative value.	
									Albumen.	Carbo-hydrates.	Fat.		Value of food in shillings per cwt.	Meadow hay as standard.
GREEN FODDER—*Continued.*												As 1:		Hay =1.
Green maize, ...	...	82·2	1·1	16·7	1·2	4·7	10·3	0·5	0·8	9·9	0·2	8·0	0·61	0·20
N. China sugar-cane (*Sorchum saccharatum*), .	...	77·3	1·1	21·6	2·5	6·7	11·7	0·7	1·6	11·9	0·3	7·4	0·89	0·29
Millet, ...	In flower.	70·0	1·9	28·1	3·7	10·2	13·4	0·8	2·1	14·2	0·3	7·1	1·10	0·36
Red clover, . . .	Before flowering.	83·0	1·5	15·5	3·3	4·5	7·0	0·7	2·3	7·4	0·5	3·8	0·93	0·31
,, . . .	Full flower.	78·0	1·7	20·3	3·2	6·8	9·5	0·8	1·8	9·6	0·5	6·0	0·86	0·28
White clover, . . .	In flower.	80·5	2·0	17·5	3·5	6·0	7·2	0·8	2·2	7·9	0·5	4·2	0·90	0·30
Swedish or alsike clover, .	In blossom.	85·0	1·5	13·5	3·3	4·5	5·1	0·6	2·1	5·8	0·4	3·2	0·77	0·25
,, ,, .	In full flower.	82·0	1·8	16·2	3·3	6·0	6·3	0·6	1·8	6·9	0·3	4·3	0·74	0·24
Lucerne, ...	Very young.	81·0	1·7	17·3	4·5	5·0	7·2	0·6	3·5	7·3	0·3	2·3	1·16	0·38
,, ...	In blossom.	74·0	2·0	24·0	4·5	9·5	9·2	0·8	3·2	9·1	0·3	3·1	1·16	0·38
Sainfoin, ...	In flower.	80·0	1·5	18·5	3·2	6·5	8·2	0·6	2·1	8·0	0·3	4·1	0·85	0·28
Crimson clover, . .	...	81·5	1·6	16·9	2·7	6·2	7·3	0·7	1·5	7·5	0·3	5·5	0·69	0·23
Trefoil, ...	...	80·0	1·5	18·5	3·5	6·0	8·2	0·8	2·2	8·7	0·5	4·6	0·93	0·31
Bokhara clover, . .	...	87·5	2·1	10·4	2·9	3·6	3·5	0·4	1·6	3·9	0·2	2·7	0·56	0·18

Serradella,	...	80·0	1·8	18·2	3·0	5·2	8·9	1·1	1·9	8·9	0·7	5·6	0·89	0·29
Lupines,	...	85·3	1·2	13·5	3·1	3·5	6·6	0·3	2·3	6·9	0·1	3·1	0·89	0·28
Field beans,	In blossom.	87·3	1·0	11·7	2·8	3·5	5·1	0·3	2·0	5·2	0·2	2·8	0·71	0·23
Vetches,	In flower.	82·0	1·8	16·2	3·5	5·5	6·6	0·6	2·5	6·7	0·3	3·0	0·90	0·30
Peas,	...	81·5	1·5	17·0	3·2	5·6	7·6	0·6	2·2	7·4	0·3	3·7	0·86	0·28
Spurry,	...	80·0	2·0	18·0	2·3	5·3	9·7	0·7	1·5	9·8	0·3	7·0	0·78	0·26
Buck wheat,	...	85·0	1·4	13·6	2·4	4·2	6·4	0·6	1·5	6·6	0·4	5·1	0·66	0·22
Young thistles (futterdistel),	...	86·7	2·0	11·3	2·9	1·4	6·1	0·9	2·2	6·0	0·6	3·4	0·83	0·27
Broom,	...	51·5	4·0	44·5	4·5	21·0	17·0	2·0	2·3	17·1	0·8	8·3	1·31	0·43
Heath (sweet broom) (*Genista Anglica*),	...	54·6	3·7	41·7	3·7	19·7	15·1	3·0	1·9	15·6	1·0	9·5	1·18	0·39
Leaves,	End of July.	55·0	3·8	41·2	5·6	7·6	26·5	1·5	3·8	24·5	0·9	6·9	1·98	0·65
Rape,	...	87·0	1·6	11·4	2·9	4·2	3·7	0·6	2·0	4·8	0·4	2·9	0·71	0·23
	...	84·7	1·6	13·7	2·5	2·4	8·1	0·7	1·8	8·2	0·4	5·2	0·80	0·26
White cabbage,	...	89·0	1·2	9·8	1·5	2·0	5·9	0·4	1·1	6·0	0·2	5·8	0·52	0·17
Cabbage stalks,	...	82·0	1·9	16·1	1·1	2·8	11·9	0·3	0·8	11·5	0·2	15·0	0·67	0·22
Carrot leaves,	...	82·0	3·6	14·2	3·2	3·0	7·1	1·0	2·2	7·0	0·5	3·8	0·86	0·28
Mangel leaves,	...	90·5	1·8	7·7	1·9	1·3	4·0	0·5	1·2	4·0	0·2	3·7	0·47	0·16
Cabbage-turnip leaves,	...	88·4	2·3	9·3	2·1	1·6	5·2	0·5	1·5	5·1	0·3	3·9	0·59	0·19
Kohl-rabi leaves,	...	85·0	1·8	13·2	2·8	1·4	8·2	0·8	2·0	7·6	0·4	4·3	0·82	0·27
Jerusalem artichoke, green,	...	80·0	2·7	17·3	3·3	3·4	9·8	0·8	2·0	9·4	0·4	5·2	0·90	0·30
Sour hay, from maize,	...	83·5	1·1	15·4	1·2	5·3	8·0	0·9	0·8	8·6	0·4	12·0	0·57	0·19
,, from half-ripe lupines,	...	79·9	2·9	17·2	3·1	6·8	6·5	0·8	2·4	7·0	0·3	3·2	0·89	0·29
III. STRAW.														
Winter wheat,	...	14·3	4·6	81·1	3·0	44·0	32·6	1·5	0·8	31·9	0·4	41·1	1·51	0·50
Winter rye,	...	14·3	4·1	81·6	2·5	48·0	29·8	1·3	0·7	32·8	0·4	48·3	1·52	0·50
Winter spelt,	...	14·3	5·0	80·7	2·5	45·0	31·8	1·4	0·7	32·1	0·4	47·3	1·49	0·49
Winter barley,	...	14·3	5·5	80·2	3·3	43·0	32·5	1·4	0·8	31·4	0·4	40·5	1·47	0·48
Spring barley,	...	14·3	4·1	81·6	4·0	40·0	36·2	1·4	1·4	36·9	0·4	27·1	1·86	0·61
Oats,	...	14·3	4·0	81·7	3·5	42·0	34·2	2·0	1·3	37·4	0·6	29·9	1·87	0·62
Vetch,	...	16·0	4·5	79·5	7·5	42·0	29·0	1·0	3·4	31·9	0·5	9·8	2·15	0·71

TABLE SHOWING THE AVERAGE COMPOSITION OF VARIOUS KINDS OF FOOD, AND THE COMPARATIVE VALUE OF EACH—*Continued.*

Description of Food.	Quality and Condition when cut.	Water.	Ash.	Organic matter.	Albuminoids.	Crude fibre.	Extractive matter, free from Nitrogen.	Fat, etc.	Nourishing Constituents. Albumen.	Nourishing Constituents. Carbo-hydrates.	Nourishing Constituents. Fat.	Ratio of Albuminoids to Carbo-hydrates.	Comparative value. Value of food in shillings per cwt.	Comparative value. Meadow hay as standard.
STRAW—*Continued.*												As 1:		Hay =1.
Peas,	...	16·0	4·5	79·5	6·5	38·0	34·0	1·0	2·9	33·4	0·5	12·0	2·16	0·71
Beans,	...	16·0	4·6	79·4	10·2	34·0	34·2	1·0	5·0	35·2	0·5	7·3	2·66	0·88
Pulse,	Middling.	16·0	4·5	79·5	8·1	38·0	32·4	1·0	3·8	33·5	0·5	9·7	2·30	0·76
,,	Very good.	16·0	5·1	78·9	10·2	34·5	33·2	1·0	5·0	34·6	0·6	7·2	2·64	0·87
Lentil,	...	16·0	6·5	77·5	14·0	33·6	27·9	2·0	6·9	30·8	1·2	4·7	3·01	1·00
Lupine,	...	16·0	4·1	79·9	5·9	40·8	32·1	1·1	2·2	41·6	0·3	19·4	2·22	0·73
Seed clover,	...	16·0	5·6	78·4	9·4	42·0	25·0	2·0	4·2	28·5	1·0	7·4	2·25	0·74
Rape,	...	16·0	4·1	79·9	3·5	40·0	35·4	1·0	1·4	35·0	0·5	25·9	1·79	0·59
Maize,	...	15·0	4·2	80·8	3·0	40·0	36·7	1·1	1·1	37·0	0·3	34·4	1·77	0·58
IV. CHAFF AND HUSK.														
Wheat,	...	14·3	9·2	73·7	4·5	36·0	35·6	1·4	1·4	32·8	0·4	24·1	1·69	0·56
Spelt,	...	14·3	8·3	77·2	3·5	40·0	32·6	1·3	1·1	33·9	0·4	31·7	1·66	0·55
Oats,	...	14·3	10·0	75·7	4·0	34·0	36·2	1·5	1·6	36·6	0·6	23·8	1·90	0·63
Rye,	...	14·3	7·5	78·2	3·6	43·5	29·9	1·2	1·1	34·9	0·4	32·6	1·70	0·56

Barley, ...	...	14·3	10·0	72·7	3·0	30·0	38·2	1·5	1·2	35·0	0·6	30·4	1·75	0·58
Vetch, ...	...	15·0	8·0	77·0	8·5	33·0	33·5	2·0	4·2	34·3	1·2	8·9	2·50	0·83
Peas, ...	...	15·0	6·0	79·0	8·1	32·0	36·9	2·0	4·0	36·2	1·2	9·8	2·53	0·83
Beans, ...	...	15·0	5·5	79·5	10·5	33·0	34·0	2·0	5·1	34·7	1·2	7·4	2·73	0·90
Lupines, ...	...	14·3	3·5	82·2	4·5	37·0	39·0	1·7	1·7	44·2	0·5	26·7	2·23	0·74
Rape, ...	...	14·0	8·5	77·5	4·0	40·6	31·3	1·6	2·0	33·4	0·7	17·2	1·89	0·62
Maize cobs, ...	...	14·0	2·8	83·2	1·4	37·8	42·6	1·4	0·6	41·7	0·4	71·2	1·85	0·61
V. Roots and Tubers.														Rye =1.
Potatoes, ...	...	75·0	0·9	24·1	2·1	1·1	20·6	0·3	2·1	20·6	0·3	10·2	1·35	0·26
Jerusalem artichoke, .	...	80·0	1·0	19·0	2·0	1·3	15·4	0·3	2·0	15·4	0·3	8·0	1·13	0·22
Mangel-wurzel, . .	...	88·0	0·8	12·2	1·1	0·9	9·1	0·1	1·1	9·1	0·1	8·5	0·63	0·12
Sugar beet, . . .	...	81·5	0·7	17·8	1·0	1·3	15·4	0·1	1·0	15·4	0·1	15·7	0·87	0·17
Carrot, ...	...	85·0	0·9	14·1	1·4	1·7	10·8	0·2	1·4	10·8	0·2	8·1	0·79	0·16
Giant carrot, . . .	...	87·0	0·8	12·2	1·2	1·2	9·6	0·2	1·2	9·6	0·2	8·4	0·69	0·14
Turnip cabbage, . .	...	87·0	1·0	12·0	1·3	1·1	9·5	0·1	1·3	9·5	0·1	7·5	0·70	0·14
Stubble turnip, . .	...	91·5	0·7	7·8	0·9	0·8	6·0	0·1	0·9	6·0	0·1	7·0	0·47	0·09
Turnip, ...	...	92·0	0·7	7·3	1·1	0·8	5·3	0·1	1·1	5·3	0·1	5·1	0·48	0·09
Parsnip, ...	...	88·3	0·7	11·0	1·6	1·0	10·2	0·2	1·6	10·2	0·2	6·7	0·81	0·16
VI. Corn and Seed.														
Wheat, ...	...	14·4	1·7	83·9	13·0	3·0	66·4	1·5	11·7	63·1	1·2	5·6	5·45	1·07
Spelt, ...	...	14·8	3·7	81·5	10·0	16·5	52·5	1·5	7·5	39·4	1·1	5·6	3·49	0·68
Rye, ...	...	14·3	1·8	83·9	11·0	3·5	67·4	2·0	9·9	64·0	1·6	6·9	5·10	1·00
Barley, ...	...	14·3	2·2	83·5	10·0	7·1	63·9	2·5	8·0	57·5	1·7	7·7	4·39	0·86
Oats, ...	...	14·3	2·7	83·0	12·0	9·3	55·7	6·0	9·0	41·8	4·7	6·0	4·30	0·84
Maize, ...	...	14·4	1·5	84·1	10·0	5·5	62·1	6·5	8·4	57·8	4·8	8·3	4·79	0·94
Millet (hirse), . . .	...	14·0	3·0	83·0	12·7	9·5	57·5	3·3	9·5	43·1	2·6	5·1	4·26	0·84
Buckwheat, ...	...	14·0	1·8	84·2	9·0	15·9	58·7	1·5	6·8	44·0	1·2	6·9	3·51	0·62
Rice (naked), . . .	...	14·0	0·3	85·7	7·7	1·2	75·4	0·4	6·9	71·6	0·3	10·5	4·55	0·89
Peas, ...	...	14·3	2·4	84·3	22·4	6·4	52·5	2·0	20·2	49·9	1·7	2·7	7·02	1·38
Beans, ...	...	14·5	3·1	82·4	25·5	9·4	45·9	1·6	23·0	43·6	1·4	2·1	7·40	1·45

TABLE SHOWING THE AVERAGE COMPOSITION OF VARIOUS KINDS OF FOOD, AND THE COMPARATIVE VALUE OF EACH—*Continued.*

DESCRIPTION OF FOOD.	Quality and Condition when cut.	Water.	Ash.	Organic matter.	Albuminoids.	Crude fibre.	Extractive matter, free from Nitrogen.	Fat, etc.	Nourishing Constituents.			Ratio of Albuminoids to Carbo-hydrates.	Comparative value.	
									Albumen.	Carbo-hydrates.	Fat.		Value of food in shillings per cwt.	Meadow hay as standard.
CORN AND SEED—*Continued.*												As 1:		Rye =1.
Vetches, ...	...	14·3	2·7	83·0	27·5	6·7	45·8	3·0	24·8	43·5	2·5	2·0	7·94	1·56
Lentils, ...	...	14·5	3·0	82·5	23·8	6·9	49·2	2·6	21·4	46·7	2·2	2·5	7·23	1·42
Lupines (yellow), . .	...	13·0	4·0	83·0	35·4	13·8	28·8	5·0	31·9	27·4	4·3	1·2	9·09	1·78
,, (blue), . .	...	14·0	3·2	82·8	28·0	13·2	36·3	5·3	25·2	34·5	4·5	1·8	7·88	1·54
Serradella, ...	...	12·0	3·5	84·5	21·8	20·8	35·9	6·0	16·3	28·7	4·8	2·5	5·54	1·09
Linseed, ...	...	12·3	3·4	84·3	20·5	7·2	19·6	37·0	17·2	15·3	35·2	...	8·26	1·62
Rape, ...	...	11·8	3·9	84·3	19·4	10·3	12·1	42·5	15·5	9·3	40·4	...	8·13	1·59
Hemp, ...	...	12·2	4·5	83·3	16·3	12·1	21·3	33·6	12·2	15·0	30·2	...	6·55	1·28
Poppy, ...	...	14·7	5·3	80·0	17·5	6·1	15·4	41·0	14·7	12·3	39·0	...	7·92	1·55
Madia, ...	...	8·4	4·7	86·9	20·6	22·5	5·0	38·8	15·4	3·7	36·9	...	7·54	1·48
Sunflower, ...	...	8·0	3·0	89·0	13·0	28·5	23·9	23·6	9·8	17·9	21·2	...	5·19	1·02
Cotton, ...	...	7·7	7·8	84·5	22·8	16·0	15·4	30·3	17·1	11·6	27·3	...	7·29	1·43
Gold of pleasure, . .	...	8·4	6·8	84·8	23·5	11·5	19·8	30·0	18·8	15·3	27·0	...	7·82	1·53
Sesam, ...	...	4·5	8·7	86·8	18·9	11·7	19·2	37·0	15·1	15·4	35·2	...	7·76	1·52
Earthnut, ...	...	6·3	3·2	90·5	28·2	13·9	7·2	41·2	23·7	5·8	39·1	...	9·83	1·93

Acorns (shelled),	Dry.	17·0	1·6	81·4	5·1	4·5	67·6	4·2	3·8	60·8	2·9	17·9	3·63	0·71
,, (unshelled),	Fresh.	56·0	1·0	43·0	2·0	4·5	34·2	2·3	1·4	27·4	1·6	22·4	1·60	0·31
Horse chestnuts,	,,	49·2	1·4	49·4	6·4	2·9	38·7	1·4	5·1	34·8	1·0	7·3	2·71	0·53
Apples and pears,	...	83·1	0·4	16·5	0·4	4·3	11·8	...	0·3	10·6	...	35·4	0·49	0·10
Cattle melon,	...	91·4	0·7	7·9	1·2	1·5	5·2	...	0·9	4·7	...	5·2	0·41	0·08
Pumpkin,	...	89·1	1·0	9·9	0·6	2·7	6·5	0·1	0·4	5·8	0·1	15·0	0·34	0·07
CAKES AND REFUSE.														
Sugar-beet pulp (pressed),	...	70·0	3·4	26·6	1·8	6·3	18·3	0·2	1·8	18·3	0·2	10·4	1·18	0·23
,, by centrifugal process	...	82·0	1·2	16·8	1·0	3·6	12·1	0·1	1·0	12·1	0·1	12·3	0·73	0·14
,, by maceration,	Fresh.	94·8	0·3	4·9	0·5	1·0	3·3	0·1	0·5	3·3	0·1	7·0	0·26	0·05
,,	Fermented.	92·0	0·5	7·5	0·8	1·8	4·8	0·1	0·8	4·8	0·1	6·3	0·39	0·08
Molasses,	...	92·0	1·6	6·4	2·0	...	4·4	...	2·0	4·4	...	2·2	0·66	0·13
Potato fibre, (From starch manufactory.)	...	85·0	0·4	14·6	0·8	2·3	11·4	0·1	0·8	11·4	0·1	14·5	0·66	0·13
Rye refuse,	...	70·0	0·8	29·2	6·1	2·7	18·9	1·5	5·2	17·0	1·2	3·8	2·05	0·40
Wheat refuse,	...	72·0	0·7	27·3	6·3	3·0	16·5	1·5	5·4	14·8	1·2	3·3	2·01	0·39
Gluten refuse,	...	70·0	0·4	29·6	4·6	0·1	24·4	0·5	4·6	24·4	0·5	4·6	2·13	0·42
Dry gluten,	...	11·6	1·6	86·8	68·9	0·3	16·1	1·5	68·9	16·1	1·5	0·3	17·33	3·40
Brewers' grains,	...	76·6	1·2	22·2	4·9	6·2	10·6	0·5	3·9	9·5	0·4	2·7	1·36	0·25
Malt dust,	...	8·0	6·8	85·2	23·0	17·5	42·2	2·5	18·4	38·0	1·7	2·3	6·11	1·20
Fresh malt, with sprouts,	...	47·5	1·7	50·8	6·5	4·3	38·5	1·5	5·2	34·7	1·0	7·1	2·74	0·54
Dry malt, without sprouts,	...	7·5	2·3	90·2	9·4	8·7	69·8	2·3	7·5	62·8	1·6	8·8	4·47	0·88
Wheat bran,	...	13·1	5·4	81·5	14·0	17·8	45·9	3·8	10·9	37·6	3·4	4·2	4·42	0·87
Rye bran,	...	12·5	5·2	82·3	14·5	15·0	49·3	3·5	11·3	40·4	3·0	4·2	4·63	0·91
Bran from wheat groats,	...	11·3	4·1	84·6	19·9	9·3	50·9	4·5	15·5	41·7	4·0	3·3	5·79	1·14
Maize bran,	...	12·0	2·3	85·7	8·0	12·5	61·2	4·0	6·2	50·0	3·6	9·5	3·85	0·75
Buckwheat bran,	...	14·0	3·4	82·6	17·1	14·7	46·4	4·4	13·5	38·1	3·9	3·6	5·15	1·01
Barley bran,	...	12·0	4·1	83·9	14·8	19·4	45·6	4·1	11·5	37·4	3·6	4·0	4·62	0·91
Barley meal,	...	11·1	5·7	83·2	11·6	31·9	34·8	4·9	8·1	24·4	3·4	4·1	3·26	0·64
Rice meal,	...	10·7	9·5	79·8	11·5	10·5	48·2	9·6	9·0	39·4	8·5	6·7	4·59	0·90
Rape cake,	...	15·0	7·4	77·6	30·3	13·8	23·8	9·5	24·2	18·3	7·7	1·6	7·31	1·43
Rape meal (pressed),	...	7·6	8·1	84·3	32·3	14·9	34·5	2·6	25·8	26·6	2·1	1·2	7·46	1·46

TABLE SHOWING THE AVERAGE COMPOSITION OF VARIOUS KINDS OF FOOD, AND THE COMPARATIVE VALUE OF EACH—*Continued.*

Description of Food.	Quality and Condition when cut.	Water.	Ash.	Organic matter.	Albuminoids.	Crude fibre.	Extractive matter, free from Nitrogen.	Fat, etc.	Nourishing Constituents.			Ratio of Albuminoids to Carbo-hydrates.	Comparative value.	
									Albumen.	Carbo-hydrates.	Fat.		Value of food in shillings per cwt.	Meadow hay as standard.
CAKES AND REFUSE—*Contd.*												As 1:		Rye =1.
Linseed-cake,	...	11·5	7·9	80·6	28·3	11·0	37·3	10·0	23·8	29·0	8·9	2·2	7·76	1·52
Linseed-meal (pressed),	...	9·7	7·3	83·0	34·2	6·6	37·7	4·5	28·7	29·4	4·0	1·4	8·47	1·66
Gold of pleasure seed-cake,	...	15·0	6·9	78·1	25·7	13·0	30·9	8·5	21·6	24·1	7·6	2·0	6·90	1·35
Poppy seed-cake,	...	10·0	8·4	81·6	32·5	11·4	29·6	8·1	27·3	23·1	7·2	1·5	8·19	1·61
Hemp seed-cake,	...	10·5	6·0	83·5	27·0	22·0	28·3	6·2	20·0	20·8	5·0	1·7	6·13	1·20
Beech mast-cake,	...	10·0	5·2	84·8	24·0	30·5	23·8	6·5	17·8	16·7	5·2	1·7	5·46	1·07
,, without shells,	...	12·5	7·7	79·8	37·1	5·5	29·8	7·5	33·4	28·1	6·8	1·4	8·82	1·93
Madia-cake,	...	11·2	6·7	82·1	31·6	25·7	9·8	15·0	22·1	6·9	12·8	1·7	6·86	1·35
Earthnut-cake,	...	9·8	7·1	83·1	32·1	21·9	18·8	10·3	25·7	14·5	8·3	1·4	7·58	1·49
,, without shells,	...	7·5	12·5	80·0	47·5	8·2	17·2	7·1	42·8	15·5	6·4	0·8	11·53	2·26
Walnut-cake,	...	13·7	5·0	81·3	34·6	6·4	27·8	12·5	31·1	25·0	11·2	1·7	9·58	1·88
Sunflower-cake,	...	10·0	10·6	79·4	34·2	10·9	22·1	12·2	28·7	17·2	11·0	1·6	8·68	1·70
Palmnut-cake,	...	9·1	3·6	87·3	16·3	21·5	36·4	13·1	16·3	33·5	13·1	4·1	6·56	1·29
Palmnut-meal (pressed),	...	9·0	3·9	87·1	18·5	28·6	36·7	3·3	18·5	33·8	3·3	2·3	6·12	1·20
Cocoanut-cake,	...	12·7	5·1	82·2	23·4	14·6	34·4	9·8	17·1	30·3	8·1	3·0	6·12	1·20

Candlenut-cake, . .	...	7·0	9·0	84·0	54·7	4·2	15·9	9·2	49·2	14·3	8·3	0·7	13·21	2·59
Sesamma-cake, . .	...	11·5	11·8	76·7	34·5	9·5	21·0	11·7	28·1	16·4	10·4	1·5	8·44	1·65
Cotton seed-cake, . .	Undecorticated.	11·5	6·3	82·2	24·6	20·8	30·6	6·2	18·1	14·1	5·6	1·6	5·46	1·07
” ” . .	Decorticated.	10·1	7·7	82·2	34·3	9·6	27·4	10·9	28·8	17·0	9·9	1·5	8·58	1·68
Malt dust-cake, from maize,	...	10·2	7·2	82·6	15·4	10·3	45·6	11·3	12·3	41·0	10·2	5·4	5·61	1·10
Pumpkin seed-cake, .	...	12·0	8·1	79·9	55·6	4·9	8·0	11·4	50·0	7·2	10·3	0·6	13·31	2·61
American flesh-meal, .	...	11·5	3·7	84·8	72·8	...	...	12·0	69·9	...	10·1	0·4	17·78	3·49
Cockchafer, . . .	Fresh.	70·4	2·3	27·3	18·8	4·8	...	3·7	13·0	...	3·1	0·6	3·43	0·67
” . . .	Dried.	13·5	6·7	79·8	55·5	13·9	...	10·9	38·0	...	9·1	0·6	10·03	1·97
Cow milk, . . .	...	87·5	0·7	11·8	3·2	...	5·0	3·6	3·2	5·0	3·6	4·4	1·33	0·26
Condensed milk, . .	...	21·5	2·5	76·0	10·2	...	52·9	12·9	10·2	52·9	12·9	8·3	5·86	1·15
Skim milk, . . .	...	90·0	0·8	9·2	3·0	...	5·6	0·6	3·0	5·6	0·6	2·4	1·00	0·20
Butter milk, . . .	...	90·1	0·5	9·4	3·0	...	5·4	1·0	3·0	5·4	1·0	2·6	1·04	0·20
Whey, ...	...	93·3	0·6	6·1	0·8	...	5·0	0·3	0·8	5·0	0·3	7·2	0·42	0·08
Cream, ...	...	62·0	0·6	37·4	2·7	...	2·9	31·8	2·7	2·9	31·8	30·5	3·95	0·77

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